Preliminary
Project Management Plan for the BTeV Project

Fermilab

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Submitted, Approved, and Accepted By:

BTeV

J. Butler
BTeV Project Director

S. Stone
BTeV Collaboration Spokesperson

M. Lindgren
BTeV Project Manager

Department of Energy

R. Lutha
DOE BTeV Project Director

P. Philp
DOE BTeV Deputy Project Director

Fermilab

J. Cooper
Head of Particle Physics Division

V. White
Head of Computing Division

R. Dixon
Head of Accelerator Division

R. Kephart
Head of Technical Division

H. Montgomery
Associate Director for Research

K. Stanfield
Deputy Director

M. Witherell
Director

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Project Management Plan for the BTeV Project

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1 INTRODUCTION

The BTeV Project Management Plan describes the physics, technical, cost, and schedule objectives for the BTeV Project, which provides the interaction region, supporting experimental facilities and detector for the BTeV experiment, Fermilab Experiment E918. It serves as a supplement to the "DOE Project Execution Plan for the BTeV Project" (the PEP), and provides further details specific to the BTeV Project.

1.1 Historical Background

The High Energy Physics (HEP) program of the Department of Energy (DOE) Office of Science conducts basic research into the nature and interactions of the fundamental constituents of matter. A major component of the US HEP program is the Fermi National Accelerator Laboratory (Fermilab) and its Tevatron Collider. The BTeV experiment will study Rare and CP-violating decays of particles containing bottom quarks and charm quarks in proton-antiproton collisions produced by the Tevatron Collider. The ultimate goal is to discover physics beyond the Standard Model or to help interpret new physics discovered elsewhere by observing its implications in these heavy quark decays.

The BTeV experiment, E918, was first proposed in May of 2000, after several stages of pre-proposal activity and evaluation, and was recommended for approval by the Fermilab Program Advisory Committee (PAC) in June of 2000, a recommendation accepted by the Fermilab Director. In order to reduce the resource requirements of the project in recognition of the evolving DOE/HEP budget realities, the project was de-scoped and resubmitted to Fermilab in its reduced form in April 2002. The PAC again recommended it for approval and the Fermilab Director granted approval. The detector, whose construction is a major part of this project, is the de-scoped version that was approved in April of 2002. The construction of the experiment was endorsed by the Particle Physics Project Prioritization Panel (P5), a subpanel of HEPAP, and their recommendation was adopted by HEPAP on September 30, 2003. The project appears in the Office of Science plan "Facilities for the Future of Science – a Twenty-Year Outlook" as a near-time priority project.

1.2 The BTeV Project

The purpose of the BTeV Project is to design, construct, and install the BTeV detector, interaction region, and supporting experimental facilities needed to achieve the physics goals set out in the BTeV Proposal Update of April 2002. Beginning in CY 1998, an effort has been underway to carry out conceptual design activities and R&D to be able to construct this detector. This has resulted in a detailed technical design, described in the BTeV Detector Technical Design Report. Parallel efforts to design and specify the components of the Interaction Region, usually referred to as the "IR", and develop a conceptual design began in 2000. At the same time a project was initiated to design and specify the changes that need to be made in and around the C0 interactions region of the collider to support the BTeV experiment. This activity is referred to as the "C0 Outfitting' (sub)project. The implementation of all three of these components, BTeV detector, C0 Interaction Region and C0 Outfitting is referred to as the "BTeV Project" and is the subject of this Project Management Plan.

The principal elements of the BTeV Detector sub-project are:

(a) modification and installation of an existing an analysis magnet, construction of two toroids (using existing steel), and construction of beam pipes that provide the physical infrastructure of BTeV experiment; (b) construction of a silicon pixel vertex detector to reconstruct primary interaction vertices and secondary decay vertices and which can be used in the lowest level trigger of the experiment; (c) construction of a Ring Imaging Cerenkov counter (RICH) to provide charged hadron identification; (d) construction of a high resolution, highly segmented electromagnetic calorimeter to reconstruct photons and π^{o}'s; (e) construction of a muon detector that can also be used in a stand-alone lowest level trigger; (f) building of a forward tracker based on straw detector technology that covers large angles with respect to the beam and provides tracking in the downstream part of the detector and improves the momentum measurement obtained from the pixel detector alone; (g) building of a forward tracker based on silicon microstrip technology that covers small angles with respect to the beam to provide tracking in the downstream part of the detector; (h) construction of a three level trigger system, including all hardware and software, which is highly efficient for a large variety of bottom and charm decays and achieves excellent rejection of light-quark events; (i) building of a data acquisition system and all necessary interfacing electronics and software to record all events containing a wide variety of bottom and charm decays; and (j) installation in the C0 collision hall, alignment, integration, debugging, and technical commissioning (described below) for all components.

The principal elements of the C0 Interaction Region subproject are:

Construction of a straight section and installation of the BTeV Vertex Magnet and a wire target station for parasitic testing of BTeV detector components as they are completed. and upgrading of the C0 Interaction region to produce high luminosity, 1 to $2\text{x}10^{32}/\text{cm}^2$-s to enable BTeV to achieve its design sensitivity. This requires the design of a low-β insertion to have collisions at high luminosity in the C0 Interaction Region, to construct the components to implement the design, and to install and commission the components.

The principal elements of the C0 Outfitting subproject are:

Construction of the architectural finishes, mezzanine structures, heating, ventilation, air conditioning (HVAC), process piping systems, and power to support the BTeV detector and upgrade of the C0 Service Building, including architectural modification, HVAC and power to support the Interaction Region at C0.

The goal of the complete project is to allow the experimenters, Fermilab, and DOE to meet the scientific objectives described in section 2.1. The timeframe for the Project is to begin construction in the beginning of FY 2005 (October 2004) and complete the project in FY 2010.

1.3 Overview of this Document

This document describes the BTeV Project, the project objectives, organization, management, and review mechanisms. The document supplements the PEP by providing additional details specific to the management of the BTeV Project. Section 2 describes the mission justification, including scientific, technical, cost, and schedule objectives.

Section 3 describes the Management, Organization, and responsibilities of the various participants. The following 9 sections describe the detailed project objectives, along with a more detailed description of the project, followed by the work plan that will allow us to realize the Project, as well as the resources needed to construct the project. They address the Work Breakdown Structure (section 4), Resource plan (section 5), Technical, cost, and schedule baselines (section 6), change control thresholds (section 7), risk management techniques (section 8), the Project Controls System (section 9), the Acquisition Strategy Plan (section 10), technical issues (section 11), and the principles of the Safety Management System (section 12). These are the procedures that will be implemented to assure an on-time and on-budget completion of the project.

2 JUSTIFICATION OF MISSION

This section describes the scientific, technical, cost, and schedule objectives that define and justify the mission and goals of the project.

2.1 Scientific Objectives

The purpose of the project is to construct the BTeV detector and install it in the C0 Collision Hall and Counting Room in a state ready to take data and to provide it with a source of high luminosity proton-antiproton collisions in the C0 IR. The detector, a forward spectrometer, covers the forward rapidity region with respect to the antiproton beam. The detector will permit the experimenters to study the decays of produced particles containing b-quarks and charm quarks to search for CP violation, mixing and other rare processes. The ultimate goal is to find physics that is not described by the Standard model description of these processes and therefore represents "new physics" beyond the Standard Model. The key areas where BTeV excels are in the ability to study decays of the B_S meson and the study decays of B mesons and baryons that contain photons and π^o's in the final state and to accumulate large statistics samples of B meson and charm meson decays that are almost independent of the final decay products. Achievement of the necessary sensitivity requires modifications to the accelerator to produce high luminosity at the C0 interaction region.

2.2 Technical Objectives

The BTeV Detector must operate successfully in the Tevatron Collider at an instantaneous luminosity of 2×10^{32} cm^{-2} sec^{-1} with bunch crossing times of either 132 ns, 264 ns, or 396 ns. All detector subsystems must be able to withstand the accumulated radiation dose corresponding to an integrated luminosity of $20fb^{-1}$. The detector must be capable of selecting proton-antiproton collision events of interest, in real-time, from the approximately fifteen million collisions per second in the Collider. Detector systems must be sufficiently reliable to assure overall efficiencies of operation of greater than 90%.

To meet the scientific and technical objectives for the BTeV experiment, the following goals must be achieved:

- The Fermilab Tevatron must be modified (mostly in the vicinity of C0) to produce high luminosity, between 1 and 2×10^{32} /cm^2-s, at the C0 interaction region in the center of the C0 Collision Hall, where the BTeV detector will be located.
- The Facilities around the C0 Hall and Counting Room must be augmented to support the BTeV Detector and the components of the IR
- The BTeV Detector must be constructed:
  - The BTeV analysis magnet and compensating dipoles, the muon toroids, the beam pipe, and other supporting physical infrastructure must be installed in C0. All systems must be constructed and installed so as to meet the requirements set forth in the BTeV Technical Design Report.

- The silicon pixel detector, forward straw tracker, forward silicon microstrip tracker, Ring Imaging Cerenkov Counter, Electromagnetic Calorimeter, and Muon Detector and all associated electronics and support systems must be constructed and installed in the C0 interaction region, integrated, and checked out. All systems must be constructed and installed so as to meet the requirements set forth in the BTeV Technical Design Report.
- The trigger system and Event Readout and Control System (data acquisition, a.k.a. DAQ) must be constructed, developed, installed and checked out . All systems must be constructed and installed so as to meet the requirements set forth in the BTeV Technical Design Report.
- The full system must be integrated so that it can accept beam collisions.

In order to maximize the data-taking cycle of BTeV, the above systems must be installed and commissioned in an efficient and timely manner. An integrated plan for these activities, under a separate WBS heading, has been developed.

Subsystem requirements are derived from the following operational goals for the BTeV detector to be achieved after installation and commissioning of the Project:

2.3 Cost Objectives

The estimated total project cost is summarized Table 7.3 of the PEP. The funding plan for the Project is summarized in Table 6.1 of the PEP. In addition to support from the DOE, funding is being sought from BTeV collaborators both in the United States and abroad, from the National Science Foundation, and the INFN (Italy).

2.4 Schedule Objectives

The primary schedule objectives for the project are summarized in Table 3. The schedule is based on the laboratory schedule given in the PEP. In order to meet the challenge of competition from LHCb, BTeV will install key infrastructure components in the C0 Collision Hall in shutdowns projected for installation of accelerator and detector upgrades for Run 2. By taking advantage of shutdown periods, BTeV will then be in a position to carry out parasitic installation of detector components as they are completed. Commissioning using parasitic beam can take place immediately after installation and checkout. The open structure of BTeV facilitates this approach, which would be impossible for a hermetic, central detector. on the aggressive schedule planned by FNAL and BTeV, completion of the full detector is scheduled for calendar 2009, when a major shutdown is scheduled to install the C0 interaction region components. This is well ahead of the proposed CD-4 date.

2.5 Project Description

The detailed Project description is provided in the BTeV Technical Design Report. In the following sections we describe the main elements of the project and provide a brief description of the work that needed to build the BTeV detector, the high luminosity IR, and to accomplish the C0 Outfitting work.

2.5.1 The BTeV Detector

The BTeV Detector is situated at the C0 interaction region of the Tevatron. It spans an angular acceptance from close to 0^{o} up to ~300 mr. It is comprised of the various components described below. The project also includes connecting and interconnecting the various components, providing computer readout of signals and data, providing various services including electrical power and various special gases, and installing all the components.

2.5.1.1 Vertex Magnet, Toroids, and Beam pipe

The vertex magnet provides a central magnetic field of 1.5 T. It will be constructed from an existing magnet named SM3. The toroid magnets are integral to the muon detector system (see below) and also provide support for magnet dipoles that are part of the C0 interaction region magnet system (see below); they also provide shielding for the detector. The iron part of the toroids will come from the existing SM12 magnet. They will be installed on both sides of the interaction region for their support and shielding functions. The beam pipe must separate the machine vacuum from detector components outside the pixel detector. It also must be thin, almost transparent to particles.

2.5.1.2 Pixel Detector

The pixel detector has three critical functions. It must provide precision 3-dimensional position information on any charged tracks passing through it in real time so a decision can be made as to whether or not an interesting interaction occurred; this is called "triggering the experiment." It must provide information sufficient to reconstruct with precision the point in space where a particle decays into lighter charged particles. It also must be part of the system that measures the momentum of the outgoing particles. The pixel system is comprised of a set of 30 planes each ~10 cm x 10 cm containing "pixels", small rectangles 50 μm x 400 μm. These small rectangles are the sensing elements and each is connected to an electronic circuit. Signals present in these elements show where particles pass.

The sensing elements are made of silicon and are connected to electronic circuits using a process called "bump bonding." The electronics is thus attached directly to the sensing elements and must be able to resist rather large doses of radiation.

The entire system is placed in a vacuum close to the beams, which is necessary due to the high precision required in reconstructing the decay vertices of particles containing heavy quarks.

2.5.1.3 Ring Imaging Cherenkov Counter

In modern experiments dedicated to studying heavy quark decays, it has proven to be necessary to identify the kinds of charged particles produced. These include pions, kaons, protons, muons and electrons. Exploitation of the Cherenkov technique has made this possible. Charged particles moving faster than light speed in a medium generate a ring of light whose angle of emission is proportional to the particle's velocity. Since other systems measure the particle's momentum, the mass of the particle, and thus its identity, can be determined.

BTeV's RICH detector consists of two independent systems sharing the same spatial volume. The elements of the main system are a 3 m long C_4F_8O gas radiator (or equivalent), a mirror that focuses the radiated Cherenkov photons onto photodectector plane, and the photodetectors that will be either MultiAnode-PhotoMultiplierTubes(MAPMTs) or Hybrid PhotoDiodes (HPDs). This system separates pions from kaons in the momentum range 3 – 70 GeV/c. It also separates electrons and muons from pions up to momenta of 23 and 17 GeV/c, respectively; this ability is very useful because the RICH solid angle of ~300 mr is larger than both the Electromagnetic Calorimeter and Muon detector.

The second system consists of a 1 cm thick liquid C_5F_{12} radiator (or equivalent) and a set of 3" diameter photomultiplier tubes array on the sides, bottom and top of the gas volume. This system is used to separate kaons from protons for momenta up to 9 GeV/c.

The use of these systems in BTeV will greatly reduce backgrounds due to confusion of one type of particle with another.

2.5.1.4 Electromagnetic Calorimeter

Scintillating crystal calorimeters provide highly efficient detection of photons with excellent energy resolution. The coupling of this technology to magnetic detectors was first done around 1990 with the advent of the CLEO II detector, and a great deal of ground breaking physics was done with the calorimeter. CMS, one of the two large detectors at the LHC, has developed a radiation hard crystal, $PbWO_4$, for use in a high radiation environment. BTeV will use $PbWO_4$ as the main element in its EM calorimeter. The crystals are approximately 2.8 cm x 2.8 cm x 22 cm and are tapered to point approximately at the interaction region. Unlike CLEO and CMS, the BTeV crystals will be in a very small magnetic field so photomultiplier tubes can be used. This will result in excellent energy resolution, especially at the lower end of the momentum range for BTeV. This resolution will be unsurpassed in any heavy quark experiment at a hadron machine. Furthermore the small transverse size coupled with the energy sharing between the crystals results in excellent angular resolution.

The crystals produce a light signal that is proportional to the incident photon energy. The light is read out with low noise 1" diameter photomultipler tubes. The signals are digitized by a special low noise circuit called a QIE that has been developed by Fermilab and used in other experiments. The system is housed in a light-tight, temperature controlled low mass structure that surrounds the beam pipe and extends laterally outward.

2.5.1.5 Muon Detector

Muons distinguish themselves from hadrons by having the ability to penetrate through thick material such as iron. In BTeV, we also magnetize the iron by using a toroidal field. This bends the muon candidates and we check if their measured momentum through the iron equals that measured by going through the vertex magnet. Two 1 m thick iron slabs taken from the existing SM12 magnet are used as toroids by winding the appropriate coils and applying current. Three sets of wire chambers are used to track the particles. The first two are positioned immediately after the iron and the third after a gap of 1 m. The wire chambers are made of thin walled 3/8" diameter stainless steel tubes with a single wire pulled down the center of each tube. The tubes are arranged at three different angles with respect to each other, named "r," "u," and "v" views. The muon detector is not only used to identify muons but plays an important role by being used to trigger the detector on the presence of dimuons, i. e. events with two muons being present. These such events often come from the decays of a J/ψ meson and this becomes a very useful check of the main detached vertex trigger.

2.5.1.6 Forward Straw Tracker

The system used to track charged particles is comprised of the Straw Tracker and inside of it, closer to the beam where the rates are high, the Forward Silicon Microstrip Detector. (The Pixel system is also used.) The Straw Tracker is made up of 4 mm diameter thin plastic tubes with a wire in the center. This technology is well suited to BTeV. The material is kept low so as not to multiple scatter charged particles or convert photons. If a wire breaks it is enclosed in the straw and the damage doesn't propagate. Excellent spatial resolution is available, better than 150 μm. A great deal of effort has been put into straw development for the LHC and previous experiments. Excellent radiation hardness has been demonstrated. In BTeV there are 7 stations or coordinate measuring positions in the Z direction along the beam line. In each station three views are measured. These are along the non-bend direction (X) and at $+/-11.3^{o}$ with respect to Y.

2.5.1.7 Forward Silicon Microstrip Detector

Due to high occupancies in the 4mm diameter straws, it was necessary to have a much better segmentation close to the beam. Single-sided silicon detectors were chosen to fill this gap. The detectors have a thickness of 300 μm of silicon with a 100 μm pitch. A planar geometry is used with the electronics positioned at the periphery. The strip geometry is matched to that of the Forward Straw Detector.

2.5.1.8 Trigger System

The interaction rate at the Tevatron at the design luminosity of $2x10^{32}$ $cm^{-2}s^{-1}$ is 15 MHz. No conceivable system can afford to record all the information from the BTeV detector at this interaction rate. We designed the readout to output events at a rate of ~4 KHz. Since we are studying bottom and charm quark decays we try to select these events to read out. The system for accomplishing this is called the "trigger." These heavy quark decays have the property that the particle containing the heavy quark moves away from the main interaction vertex before it decays and forms its own decay vertex. Our main trigger uses the pixel detector information to investigate the interaction for the presence of separated decay vertices. If one is likely to be present then the event is kept. This decision must be made in the time interval between beam crossings of 396 ns. This is accomplished using massively parallel computing with large event buffers. For most b decays the trigger efficiency is above 50% and the rejection in the first level trigger on non-b interactions is ~100:1. Further trigger levels using more of the event information are used to get to the desired 4 KHz readout rate. There is also secondary trigger on dimuons used to check the efficiency of the main detached vertex trigger. There is also an NSF funded project named "RTES" that is developing software for real time monitoring and fault tolerant running of the system.

2.5.1.9 Event Readout and Control System

This system consists of two basic parts. It must transfer data to archival storage, interfacing with the various triggering components as needed. It also needs to monitor data quality and ensure that all BTeV components are operating within design specifications.

2.5.1.10 Integration, Installation, and Commissioning

Each detector subsystem has a plan for acquiring parts, testing and assembling various subsystems before transferring to C0. There is an overall installation plan for the entire project. This includes an assembly plan. Common services, such as High Voltage, Low Voltage, and gas, are covered in this part of the project.

2.5.2 C0 Interaction Region

The Interaction Region consists of the magnets, electrostatic separators, instrumentation, controls, interlocks and supporting systems to focus the two colliding beams at the Interaction Point (IP) to create high luminosity source of proton- antiproton collisions. All components are in the beam tunnel section just outside the C0 Collision Hall. As a first step in implementing the IR and to create an opportunity for early testing of equipment in C0, the current components in C0 will be removed and replaced by a conventional straight section in a shutdown that will occur in 2005.

2.5.3 C0 Outfitting

The C0 area buildings are shells that need to be completed in order to support a complex experiment such as BTeV. In the C0 Assembly Building, the mezzanine will be converted into a three story counting room. Power will be upgraded in the area to support the counting room electronics, detector hall electronics, and the BTeV vertex magnet and toroids. The C0 Service Building will be reorganized to support the equipment required to power, monitor and control the components of the C0 IR. Upgrades to AC power in the C1 and D4 service buildings are also required.

2.5.4 Project Management

This project is managed by having procedures and roles and responsibilities as defined in this document. Briefly, Level-1 Managers, the Project Director, Deputy Project Director, and Project Manager, are appointed by the laboratory. The Project Director appoints Level-2 managers in consultation with the collaboration spokesperson. Review procedures to ensure that schedules are being met and costs kept under control have been established. Change control procedures are in place, and there is an International Finance Committee to consider the funding needs of the project and identify funding and support from within the collaboration and external to DOE funding provided through Fermilab.

3 MANAGEMENT, ORGANIZATION, AND RESPONSIBILITIES

3.1 Overview

The Project is primarily funded by the DOE and managed through Fermilab. It is carried out in collaboration with universities and laboratories in the US and other countries. Its goal is to construct the BTeV detector and to provide it with collisions to fully exploit the capabilities of the Tevatron to do world class B and charm physics in the LHC era. The Project is to be managed to a predetermined scope, cost and schedule. The responsibilities for managing the project are represented in the organization chart, Fig. 1, and are described in the following sections of this chapter.

3.2 Department of Energy

The Department has established the need for the BTeV Project by considering and responding to advice from its advisory panel, HEPAP, HEPAP's prioritization P5 subpanel, and to Fermilab requests in field task proposals, and by participating in peer review processes for the Fermilab program including the annual DOE laboratory-wide review and the Fermilab Physics Advisory Committee meetings. The BTeV Project appears in the DOE's Office of Science plan "Facilities for the Future of Science – a Twenty-Year Outlook" as a near-term priority project. The Project was given CD-0 approval in February of 2004. The Department of Energy provides the majority of funding for the Project. These funds are provided through the annual Fermilab financial plan by contract modification. The Division of High Energy Physics provides annual program guidance to the laboratory as well as annual guidance on the funding profile for the project. The Department exercises oversight of the Project by:

- conducting periodic reviews of the project;
- participating in regularly scheduled Project Management Group (PMG) meetings;
- overseeing operations and fabrication activities;
- monitoring project progress via monthly reports; and
- monitoring milestones and performance measures.

The National Science Foundation is also expected to provide significant funding for BTeV. Funds and support for in-kind contributions are anticipated from INFN and other funding agencies from the nations of universities and laboratories collaborating on BTeV. The DOE and Fermilab regularly involve the relevant agencies in all the oversight activities described in this document.

The definition of the project, control of its scope, allocation of Project contingency, oversight and interaction with the collaborating institutions and agencies are the responsibility of the Project Director. The Project Manager has the responsibility and authority for managing the project to deliver the approved scope within the total project cost estimate and on schedule. The management structure of the Project for the DOE is described in detail in the PEP.

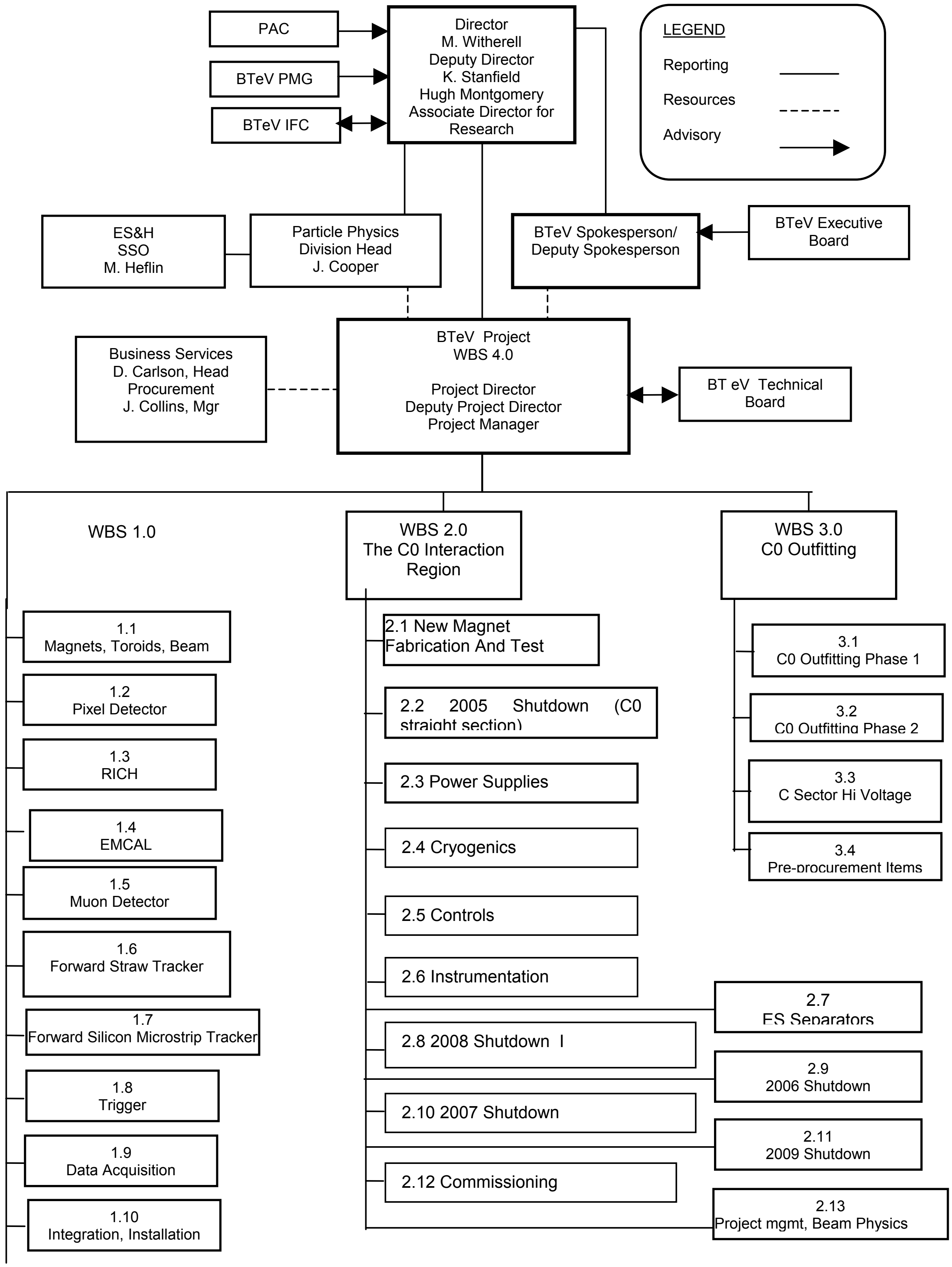

Figure 1 Organization chart for the BTeV Project through WBS Level 2

3.3 Fermilab Director

The Fermilab Director is responsible to the Universities Research Association and the Department of Energy for the successful completion of the Project and only he/she is authorized to commit funds appropriated for Laboratory use. The Director approves the scope of the Project with advice from the Fermilab Physics Advisory Committee (PAC) in response to proposals from the BTeV Collaboration. Decisions regarding the scope of the project are made in a two-stage process. Stage I approval is given to endorse the scientific merit of the proposal when sufficient information is known regarding technical designs so that costs and schedules can be estimated. Resources can then be allocated so that a Project Management Plan can be developed, detailed technical designs can be prepared, and cost estimates and resource-loaded schedules can be made. In addition, a financial plan identifying the necessary funding resources must be prepared. Upon the successful completion of these plans, Stage II approval is granted by the Director upon advice of the PAC. Approval for the project may proceed in parts, subsystem by subsystem. Construction of a subsystem normally begins after Stage II approval has been granted for that subsystem but may proceed earlier with the Director's approval.

The Director approves or concurs with the contents of the Technical Design Report (TDR), the Project Management Plan (PMP), the cost estimate, the schedule, the financial plan, and changes in scope for the Project.

3.4 Fermilab Deputy Director

The Director has delegated certain responsibilities and authority to the Deputy Director. The Deputy Director is responsible for management oversight of the Project. Oversight of the Project will be implemented in part through reviews including the Project Management Group (section 3.20.2) and/or Director’s Reviews. The Deputy Director chairs the Project Management Group and charges Director’s Review panels. Along with routine interactions with project management, these reviews will identify actions and initiatives to be undertaken to achieve the goals of the Project including allocation of financial and human resources. Progress will also be monitored through presentations to and discussions with the PAC. The Deputy Director advises the Director on the approval of the TDR, PMP, cost estimate, schedule, and financial plan and concurs with these approvals. He/she is responsible for providing a funding profile consistent with Laboratory funding after consultation and guidance from the DOE program office.

3.5 Fermilab Associate Director for Research

The Deputy Director has delegated some aspects of BTeV responsibilities to the Associate Director for Research. To implement the work plan for the Project, BTeV Memoranda of Understanding are executed with collaborating institutions. The Associate Director for Research, with the concurrence of the Deputy Director and Director, approves all BTeV Institutional Memoranda of Understanding (MoU) related to the Project. The Associate Director also chairs the International Finance Committee, which coordinates support of the BTeV project by foreign funding agencies.

3.6 Fermilab Particle Physics Division Head

The Fermilab Director and Associate Director for Research have delegated certain responsibilities and authorities to the Fermilab Particle Physics Division (PPD) Head. The PPD Head provides oversight for PPD financial resources, human resources, technical resources, space resources, and Environmental, Safety, and Health (ES&H) monitoring for the Project.

The PPD Head and his/her deputies are members of the Project Management Group. The PPD Head advises the Associate Director for Research on approval of BTeV Memoranda of Understanding relevant to PPD resources and concurs in these approvals. The PPD Head advises the Director and Deputy Director on approval of the PMP and the Cost/Schedule Plan (CSP) and concurs with these approvals.

On guidance from the Director, the PPD Head allocates yearly budgets to the Project. These project funds are then administered by the Project Director and Project Manager, according to the responsibilities described below, within the context of PPD procedures and policies and with the support of the PPD budget office.

The PPD is the primary source of Fermilab manpower and technical resources for the Detector part of the project, as well as the project management activity. The PPD Head and his/her designees make long-term assignments of PPD manpower directly to the project in consultation with the Project Manager and the Project Director and in accordance with the CSP. The Project Manager then deploys these people to achieve the project goals, reporting changes in assignments to the PPD Head. The PPD Head maintains line management responsibility for these PPD employees.

The BTeV Project is an organizational unit of the PPD. The PPD provides the personnel to staff the BTeV Project Office. The PPD also provides support to the project through PPD technical resource groups. This is done in accordance with the CSP via specific work plans or BTeV Memoranda of Understanding. The PPD Head maintains direct line management responsibility for such PPD resources.

Since the PPD is the primary source for providing the Fermilab labor needed to achieve the project schedule goals for the detector, labor shortfalls must be reported in a timely fashion. The PPD head or designee will advise the Project Manager, Project Director, and Deputy Director on the availability and sufficiency of labor resources to meet the project plan as indicated in the CSP. In the event of any mismatch in the availability of labor resources and the requirements, the Project Manager will conduct a schedule impact study and report to the BTeV Project Director, who will consider possible workarounds and propose a schedule variance in the event of a schedule impact to the Deputy Director as required by the project controls.

3.7 Fermilab Computing Division Head

The Computing Division is providing a significant fraction of the resources in the area of trigger (WBS 1.8) and data acquisition (WBS 1.9). This responsibility includes both hardware and software.

The CD Head and her/his deputies are members of the Project Management Group. The CD Head advises the Associate Director for Research on approval of BTeV Memoranda of Understanding relevant to CD resources and concurs in these approvals. The CD Head advises the Deputy Director and Associate Director for Research on approval of the PMP and the Cost/Schedule Plan (CSP) and concurs with these approvals.

The CD is the primary source of Fermilab manpower and technical resources for the trigger and data acquisition parts of the project. The CD Head and her/his designees make long-term assignments of CD personnel directly to the project in consultation with the Project Manager and in accordance with the CSP. The Project Manager then deploys these people to achieve the project goals, reporting changes in assignments to the CD Head. The CD Head maintains line management responsibility for these CD employees.

The CD also provides support to the project through CD technical resource groups. This is done in accordance with the CSP via specific work plans or BTeV Memoranda of Understanding. The CD Head maintains direct line management responsibility for such CD resources.

Since the CD is the primary source for providing the Fermilab labor needed to achieve the project schedule goals in the area of trigger and data acquisition, labor shortfalls must be reported in a timely fashion. The CD head or designee will advise the Project Manager, Project Director, and Deputy Director on the availability and sufficiency of labor resources to meet the project plan and report to the BTeV PMG any mismatch in the availability of labor resources and the requirements of the CSP. In the event of any mismatch in the availability of labor resources and the requirements, the Project Manager will conduct a schedule impact study and report to the BTeV Project Director, who will consider possible workarounds and propose a schedule variance as appropriate to the Deputy Director as required by the project controls in the event of a schedule impact.

3.8 Fermilab Accelerator Division Head

The Accelerator Division is providing a significant fraction of the resources for the IR subproject, which provides collisions at high luminosity in the C0 IR, WBS 2.0. In addition, the BTeV detector has components that are inside the Tevatron vacuum system and others that closely surround it. Impact on the Tevatron could occur as early as 2005. Moreover, due to the open nature of the detector, partial installation of components is foreseen after about 2006, while CDF and D0 are still taking data. Moreover, the Accelerator Division has a significant role and interest in the C0 Outfitting subproject, both from a design, technical and implementation point of view and from a programmatic point of view (possible interference with operations).

The Accelerator Division Head and his/her deputies are members of the Project Management Group. The Accelerator Division Head advises the Deputy Director on the approval of the BTeV Baseline design as it affects the Tevatron, and on scheduling issues with respect to design, construction, and installation of the C0 IR during the project. It must also advise on BTeV experiment operations in the IR during the project period. The AD Head advises the Deputy Director on approval of BTeV Memoranda of Understanding relevant to AD resources and concurs in these approvals. The AD Head advises the Director and Deputy Director on approval of the PMP and the Cost/Schedule Plan (CSP) and concurs with these approvals.

The Accelerator Division must review and approve BTeV designs that could affect the operation of the Tevatron or its safety, including the baseline design. Once designs are approved, these will constitute an agreement between the BTeV Project and the Accelerator Division to operate the equipment delivered in the agreed upon manner. Reviews must take place on a schedule that is consistent with BTeV project milestones.

Since the AD is one of the primary sources for providing the Fermilab labor needed to achieve the project schedule goals in the area of the C0 IR design and implementation, labor shortfalls must be reported in a timely fashion. The AD head or designee will advise the Project Manager, Project Director, and Deputy Director on the availability and sufficiency of labor resources to meet the project plan and report to the BTeV PMG any mismatch in the availability of labor resources and the requirements of the CSP. In the event of any mismatch in the availability of labor resources and the requirements, the Project Manager will conduct a schedule impact study and report to the BTeV Project Director, who will consider possible workarounds and propose a schedule variance as appropriate to the Deputy Director as required by the project controls in the event of a schedule impact.

3.9 Fermilab Technical Division Head

The Technical Division is providing a significant fraction of the resources for the IR subproject, which provides collisions at high luminosity in the C0 IR, WBS 2.0.

The Technical Division Head and his/her deputies are members of the Project Management Group. The Technical Division Head advises the Deputy Director on the approval of the BTeV Baseline design as it affects the IR and the support of the components it has provided, and on scheduling issues with respect to design, construction, installation and of the C0 IR during the project. The TD Head advises the Deputy Director on approval of BTeV Memoranda of Understanding relevant to TD resources and concurs in these approvals. The TD Head advises the Director and Deputy Director on approval of the PMP and the Cost/Schedule Plan (CSP) and concurs with these approvals.

Since the TD is one of the primary sources for providing the Fermilab labor needed to achieve the project schedule goals in the area of the C0 IR design and implementation, labor shortfalls must be reported in a timely fashion. The TD head or designee will advise the Project Manager, Project Director, and Deputy Director on the availability and sufficiency of labor resources to meet the project plan and report to the BTeV PMG any mismatch in the availability of labor resources and the requirements of the CSP. In the event of any mismatch in the availability of labor resources and the requirements, the Project Manager will conduct a schedule impact study and report to the BTeV Project Director, who will consider possible workarounds and propose a schedule variance as appropriate to the Deputy Director as required by the project controls in the event of a schedule impact.

3.10 Facilities Engineering Services Section Head

The Facilities Engineering Services Section (FESS) is providing the most of the resources for the C0 Civil Construction subproject., WBS 3.0.

The FESS Head and his/her deputies are members of the Project Management Group. The FESS Section Head advises the Deputy Director on the approval of the BTeV Baseline design as it affects the outfitting of the C0 area and the support of the components it has provided, and on scheduling issues with respect to design, construction, and installation of modifications to the C0 area to support the BTeV experiment. The FESS Head advises the Deputy Director on approval of BTeV Memoranda of Understanding relevant to FESS resources and concurs in these approvals. The FESS Head advises the Director and Deputy Director on approval of the PMP and the Cost/Schedule Plan (CSP).

Since FESS is the primary source for providing the Fermilab labor needed to achieve the project schedule goals in the area of the C0 Outfitting, labor shortfalls or contractor delays and problems must be reported in a timely fashion. The FESS head or designee will advise the Project Manager, Project Director, and Deputy Director on the availability and sufficiency of labor resources to meet the project plan and report to the BTeV PMG any mismatch in the availability of labor resources and the requirements of the CSP. In the event of any mismatch in the availability of labor resources and the requirements, the Project Manager will conduct a schedule impact study and report to the BTeV Project Director, who will consider possible workarounds and propose a schedule variance as appropriate to the Deputy Director as required by the project controls in the event of a schedule impact.

3.11 Fermilab Particle Physics Division Senior Safety Officer and Senior Safety Officers of Beams, Computing, and Technical Divisions

The PPD Senior Safety Officer (SSO) reports to the PPD Head and is responsible for ES&H issues in PPD. The SSO has part of the ES&H oversight responsibility for the

BTeV Project. The PPD Safety Officer coordinates any activities and facilitates the resolution of any issues that cut across various Divisions.

The AD Senior Safety Officer (SSO) reports to the AD Head and is responsible for ES&H issues related to the project that fall solely within AD. . The SSO has part of the ES&H oversight responsibility for the BTeV Project. The AD SSO works to resolve any issues that cut across divisional/sectional lines with the PPD SSO and the SSO's of all divisions involved in the issue.

The CD Senior Safety Officer (SSO) reports to the CD Head and is responsible for ES&H issues related to the project that fall solely within CD. The SSO has part of the ES&H oversight responsibility for the BTeV Project. The CD SSO works to resolve any issues with cut across divisional/sectional lines with the PPD SSO and the SSO's of all divisions involved in the issue.

The TD Senior Safety Officer (SSO) reports to the TD Head and is responsible for ES&H issues related to the project that fall solely within TD. . The SSO has part of the ES&H oversight responsibility for the BTeV Project. The TD SSO works to resolve any issues with cut across divisional lines with the PPD SSO and the SSO's of all divisions involved in the issue.

The Fermilab Safety Section is ultimately responsible for oversight and advice on all ES&H aspects of the BTeV Project.

3.12 BTeV Spokesperson

The BTeV Spokesperson provides the means of contact between the BTeV Collaboration and the Laboratory. He/she speaks for the Collaboration and represents the Collaboration in interactions with the Laboratory. The BTeV Spokesperson is responsible for all aspects of the BTeV Experiment, including the operation of the BTeV detector, the analysis of data and production of physics results. The Spokesperson is elected by the Collaboration. In doing so, the Collaboration consults with the Director and he/she concurs in the selection. Scope changes that have the potential to change the physics reach or physics capability of the BTeV experiment will be initiated by the spokesperson and approved by the Fermilab Director. The Spokesperson, representing the Collaboration, and after detailed discussion with the PD, seeks approval for all scope changes with the potential to have a significant impact on the physics capability of the detector by making scientific proposals to the Fermilab Director. The Fermilab Director may seek the advice of the Physics Advisory Committee when considering these proposals. The Fermilab Director approves all such scope changes, those that increase the scope as well as those that reduce it.

3.13 BTeV Deputy Spokesperson

The BTeV Deputy spokesperson reports to the BTeV Spokesperson and represents the BTeV spokesperson in all BTeV Collaboration functions when the spokesperson is not available. The spokesperson may delegate some of his/her specific duties to the deputy. The Deputy Spokesperson is elected by the Collaboration. In doing so, the Collaboration consults with the Fermilab Director and he/she concurs in the selection.

3.14 BTeV Project Director

The BTeV Project Director (PD) provides oversight, coordination, management, and direction of the BTeV Project. The Project Director is responsible for developing and coordinating support for the project from various organizations including the BTeV Project, other units within the laboratory, and institutions in the Collaboration. This support includes engineering and design, procurement and fabrication, ES&H support, administration, financing, and scheduling. He/she represents the BTeV Project in interactions with the BTeV Collaboration, FNAL, DOE, NSF, Fermilab and U.S. Institutions participating in the BTeV Project and foreign institutions and funding agencies participating in the BTeV Project. The PD is appointed by the Director of Fermilab with the concurrence of the BTeV collaboration. He/she reports to the Fermilab Director (or his/her appointed representative). A non-Fermilab BTeV collaborator may be appointed as the Project Director after receiving a Guest Scientist appointment at the Laboratory. The Project Director reports to the Spokesperson on all technical and scientific issues of the BTeV detector.

Specific responsibilities of the PD include:

a) Formulating, with the BTeV spokesperson and the BTeV Project Manager, the definition of the project and approving or, when additional approval is required, recommending any changes in the project scope, cost, or schedule.
b) Approving the Technical Design Reports for each subsystem, with the concurrence of the BTeV spokespersons and the Fermilab Deputy Director.
c) Concurring with the choice by the Fermilab Director of the Deputy PD and the Project Manager.
d) Appointing, with the advice of the Project Manager and in consultation with the BTeV spokesperson , the Level 2 Managers who are responsible for coordination and management within each major subsystem.
e) Preparing, with the Project Manager, annual funding requests to DOE and NSF for the anticipated BTeV Project activities. This takes the form of participating in the preparation of the annual Fermilab budget submission for DOE funding provided by Fermilab for the BTeV project.
f) Upon the advice of the Project Manager and the Level 2 Managers, the PD negotiates and implements Memoranda of Understanding with all participating institutions for the total project scope of work and the annual Statements of Work associated with the annual workplan in support of the BTeV Project. MOUs form agreements between the BTeV Project and BTeV Collaborating Institutions, specifying the deliverables to be provided, the schedule, and the resources available on an institution by institution basis.
g) Approves changes to the scope, cost and schedule of the project above specified thresholds.

h) Maintaining close coordination with the Fermilab Director or his/her delegatee on the progress of the BTeV project, and report promptly any problems that might benefit from the joint efforts of the PD and the Fermilab Management.
i) Interacting with Fermilab Management, and where appropriate with funding agency representatives, on issues affecting resource allocation and availability.
j) Informing and advising DOE and NSF representatives at special meetings and reviews.
k) Reviewing, approving, and transmitting the monthly report, prepared by the Project Manager, on activities, issues, performance and fiscal status of the Project
l) Making periodic reports to the PMG and the various oversight boards on the status and issues of the Project
m) Making periodic reports to the BTeV collaboration and Executive Board to ensure that the BTeV collaboration is fully informed about all important issues
n) Providing oversight of the project, including conducting internal reviews.
o) He/she reports to the Fermilab Deputy Director on all matters that have the potential to result in commitments of the Laboratory or the Universities Research Association.
p) The Project Director is in line management for the Project and has responsibility for completing the project safely and with respect for the environment.

3.15 BTeV Deputy Project Director

The BTeV Deputy Project Director reports to the BTeV Project Director and represents the BTeV Project in all functions when the Project Director is not available, including budget authority. The Project Director may delegate specific duties to the deputy, including budget authority. The Deputy PD is appointed by the Director of Fermilab and with the concurrence of the BTeV collaboration.

A non-Fermilab BTeV collaborator may be appointed as the Deputy Project Director after receiving a Guest Scientist appointment at the Laboratory.

3.16 BTeV Project Manager

The BTeV Project Manager (PM) has the responsibility and authority to manage the BTeV Project to the approved scope, cost, and schedule. The PM is appointed by the Director of Fermilab with the concurrence of the PD, and the BTeV collaboration. He/she reports to the PD. He/she assists the PD in representing the BTeV Project in interactions with the BTeV Collaboration, FNAL, DOE, NSF, Fermilab and U.S. Institutions participating in the BTeV Project and foreign institutions and funding agencies participating in the BTeV Project.

The responsibilities and authorities of the Project Manager, include:

a) Managing the project to deliver the approved scope on schedule and within the cost estimate.
b) Management coordination, integration, and planning for the BTeV Project.
c) Maintaining and updating the BTeV Project baseline cost and schedule plan;
d) Proposing changes to the project scope, cost, or schedule above specified thresholds to the Project Director;
e) Implementing and maintaining the BTeV Earned Value System;
f) Acting as liaison with the Fermilab Management on Fermilab resources and infrastructure, performance milestones, departmental and divisional issues and self-assessments;
g) With the Level 2 Managers conducts Engineering Design Reviews and Production Readiness Reviews to ensure that project organization, integration, and interface issues are addressed.
h) Preparing the monthly report and various annual and other reports and submitting them to the PD for approval and transmission
i) Providing or arranging technical support for the Level 2 Managers so that they can accomplish theirs goals.
j) Adjusting resources below specified thresholds between (among) Level 2 Project to achieve the goals of the project
k) Ensuring the achievement of project milestones.
l) Proposing and following up on corrective action when milestones are projected to be late
m) Manages and approves major project procurements and supports L2M's in preparing Request for Proposal/Quotations (RFP/RFQ's) and market surveys for large capital procurements
n) Organizing, and chairing where necessary, production readiness reviews, BTeV Project Office reviews of L2 subsystems, drafting for approval reports on proceedings, and recommending and following up on proposed actions, if required.
o) Overall schedule and technical integration
p) Ensuring the preparation of Technical Design Reports for each subsystem.
q) Appointing, with the advice of the relevant Level 2 managers and in consultation with the PD, Level 3 manages and proposing to the PD appointments and changes to the Level 2 managers
r) Quality Assurance, Risk Assessment/Management, Value Engineering, and Configuration Management for the BTeV Project.
s) Manages and oversees a BTeV Project Office within the Particle Physics Division.
t) Ensuring that all elements of the project conform to applicable U.S. and relevant foreign Quality Assurance and ES&H requirements.
u) Establishes standards and procedures by which the BTeV project is executed.
v) Updating the Project Management Plan as necessary with the approval of the signatories to this document.
w) The Project Manager may identify the need for out-of-scope changes as they arise to the PD. When there is a need for a change having a significant impact on the physics capability of the detector, the Project Director reports these to the

Spokesperson. After consultation with the Technical Board, the PD identifies the need to the Fermilab Director through the PMG. Other changes follow the change control procedure described below.

x) The Project Manager is responsible for assisting the Project Director in organizing presentations at reviews and status reports on the Project as needed to respond to the Fermilab Director and funding agencies.
y) The Project Manager is in the line management and has responsibility for completing the project safely and with respect for the environment .

The Project Manager has the responsibility of completing the Project on schedule, on budget, and within the agreed upon scope by managing the designated resources of the Laboratory and, in consultation with the Spokesperson, the designated resources of the Collaboration. He/she is responsible for monitoring expenditures of US and non-US funds. He/she tracks and reports deviations from baseline schedules and costs as specified in the Project Management Plan. The Project Manager reports to the PD on all matters related to managing the Project to the approved scope, cost, and schedule and on any changes that are proposed. He/she reports to the PD on all matters that have the potential to result in commitments of the Laboratory or the Universities Research Association.

3.17 Technical Coordinators

The Technical Coordinators, including the BTeV Project Mechanical Engineer, Electronics Engineer, and Software Engineer are appointed by the Project Manager with the concurrence of the PD and the BTeV Spokesperson. The Technical Coordinators report to the Project Manager and assist the Project Manager and the Project Director in the coordination, evaluation, and decision-making process for technical issues in the Project. They also assist the Project Manager in preparing the standards and procedures required to manage and execute the project.

3.18 BTeV Detector Project Subproject Managers

The Level 2 managers are appointed by the Project Director, with the advice of the Project Manager and in consultation with the BTeV spokesperson. They report to the PM. The Level 3 subproject Managers are appointed by the Project Manager with the concurrence of the PD. The Subproject Managers manage and direct their subprojects and report to the Project Manager. They are directly responsible for generating and maintaining the cost-estimate, schedule, and resource requirements for their subprojects. They are responsible for meeting the goals of their subproject within the accepted baseline cost and schedule. The Subproject Managers are in the line management for the project and are responsible for completing their subprojects safely and with respect for the environment.

3.19 BTeV Collaborator Responsibilities

The responsibilities of BTeV Collaborators are specified in comprehensive BTeV Memoranda of Understanding (MoU). A multi-year MoU details the work that the Collaborator has agreed to do for the Project, and includes a list of the personnel involved, and significant milestones. These agreements are updated yearly through Statements of Work (SOW) that specify the funding and commitments for the next Fiscal Year. They are negotiated by the BTeV Project Director, in consultation with the Project Manager, and are approved by the Collaborator BTeV Contact Person, appropriate responsible parties for the collaborating institution, the BTeV Spokesperson, the heads of affected Divisions, and the Deputy Director. The Project Manager has responsibility for coordinating and managing all Collaboration-wide resources identified by these MoU's and SOW's.

3.20 Advisory Functions

3.20.1 BTeV Technical Board

The Project Director and Project Manager serve as co-chairs of the BTeV Technical Board that meets frequently to discuss technical and management issues in the Project and is advisory to the Project Director and Project Manager. The group is comprised of the BTeV Spokesperson, Project Director, Deputy Project Director, Project Manager, Technical Coordinators, the WBS Level 2 Subproject Managers, additional personnel from the Project Office, and others as the need arises. It also has three at large members from the collaboration, usually drawn from universities or other national laboratories. It includes the BTeV offline computing project leader, the leader of the detector simulation project, and the leader of the BTeV event reconstruction project. The WBS Level 3 Subproject Managers often participate in these meetings. The Technical Board advises the Project Director and Project Manager on all aspects of the project including any changes to the cost, scope or schedule. It is the beginning of the change control process within BTeV and is the link to the BTeV collaboration for changes to the baseline through the participation of the BTeV Spokesperson. The meetings also provide a convenient mechanism for the dissemination of information.

3.20.2 BTeV Project Management Group

The Deputy Director chairs a Project Management Group (PMG) that meets as required to monitor the progress of the project. The meetings are attended by those who have responsibility for the Project and by those who have authority to redirect resources within the Laboratory and the Collaboration. The group normally consists of the BTeV Spokesperson and Deputy, the BTeV Project Director and Deputy and Project Manager, the Heads of participating Divisions and Sections, Laboratory Management personnel, and other representatives of Fermilab and BTeV. The PMG also serves as the Change Control Board for the project.

3.20.3 BTeV Executive Committee

The BTeV Executive Committee consists of the leaders chosen by the BTeV collaboration along with the BTeV co-spokespersons to deal with collaboration and physics issues related to the experiment. It has strong university representation and has international balance. It advises the BTeV Spokespersons on all aspects of BTeV including the BTeV Project. In particular, it is involved in all resource issues relating to the collaborating institutions.

3.20.4 BTeV International Finance Committee

The BTeV International Finance Committee consists of a BTeV physicist and a funding agency representative for non-US country providing funding or in-kind contributions to BTeV. Since much of the U.S. contribution comes through Fermilab, the Fermilab Associate Director of Research is the U.S. funding agency representative on the committee. This Committee oversees the use of financial contributions by these groups to the costs associated with the construction of the BTeV Project and operation the BTeV detector and experiment.

4 WORK BREAKDOWN STRUCTURE

All work required for completion of the Project is organized into a Work Breakdown Structure (WBS), a hierarchical ordering of tasks in outline-like form. The WBS constitutes a complete definition of the scope of the project and forms the basis for its planning, execution, and control. The foundation of the WBS for the technical components of the BTeV Project are the BTeV Technical Design Reports that thoroughly describe the design of the Detector, Interaction Region, and C0 Outfitting projects. The WBS is expressed through a resource-loaded cost and schedule (RLCS) with appropriately linked tasks. The schedule contains Materials and Services (M&S) costs, labor costs, and contingency on a task-by-task basis, as well as a series of project milestones that aid in the estimation of the project end date. The WBS structure to level 2 is shown in the organization and reporting chart above.

The major systems that comprise the Project are represented at WBS Level 2 are

WBS 1.0 The BTeV Detector:
(1.1) Vertex magnet, toroid and beampipes
(1.2) Pixel Detector
(1.3) Construction of a Ring Imaging Cerenkov counter (RICH)
(1.4) Electromagnetic calorimeter
(1.5) Muon Detector
(1.6) Forward Straw Tracker based on straw detector technology that coves
(1.7) Forward Silicon Microstrip Tracker
(1.8) Trigger system
(1.9) Data Acquisition
(1.10) Installation and Integration

WBS 2.0: The C0 Interaction Region
(2.1) New Magnet Fabrication and Test
(2.2) 2005 Shutdown
(2.3) Power Supplies
(2.4) Cryogenics
(2.5) Controls
(2.6) Instrumentation
(2.7) ES Separators
(2.8) 2008 Shutdown
(2.9) 2006 Shutdown
(2.10) 2007 Shutdown
(2.11) 2009 Shutdown
(2.12) Commissioning
(2.13) C0 IR Project Management, Beam Physics

WBS 3.0 C0 Outfitting
(3.1) C0 Outfitting Phase 1

(3.2) C0 Outfitting Phase 2
(3.3) C Sector High Voltage
(3.4) Pre-procurement items

WBS 4.0 BTeV Project Management

The task-based WBS extends downward through many additional levels to facilitate cost, schedule and resource planning. The WBS structure through Level 2 is described below.

WBS 1 BTeV Detector Project

This Level 1 summary element consists of all elements of the BTeV Detector Construction Project: Magnets, Toroids, and Beampipes; Tracking system – pixel detector, forward straw tracker, and forward silicon tracker; Particle Identification System –Ring Imaging Cerenkov Counter, Electromagnetic Calorimeter, and Muon Detector; Trigger and Data Acquisition System, and Installation and System Integration (I&I).

WBS 1.1 Vertex Magnet, Toroids, and Beampipes

This level 2 summary element covers the disassembly of the existing SM3 dipole magnet, its transportation to C0 and its reassembly with pole piece shims. It also includes assembling 4 toroid magnet sections in C0 using iron from the existing SM12 magnet. The last piece covers the installation of a thin 1" diameter beampipe from the pixel detector to the front of the RICH where it will be coupled to a recycled 2" diameter Be beampipe that was used by CDF in Run I.

WBS 1.2 Silicon Pixel Detector

This level 2 summary element covers the design, procurement, construction, and testing of a sophisticated, radiation-hard, silicon pixel vertex detector . This element includes the silicon pixel sensors, readout chip, readout electronics, mechanical supports, module production, cabling, vacuum system, assembly and installation, monitoring, software, and associated administration.

WBS 1.3 Ring Imaging Cerenkov Counter

This level 2 summary element covers constructing two virtually independent systems sharing the same physical volume. The primary system consists of gas radiator ~3 m in length using C_4F_8O (or equivalent). The Cherenkov light is focused onto a photon detector using a thin spherical mirror. The photon detector is built from Multi-Anode-Photo-Multiplier tubes. The second systems consists of a thin liquid C_5F_{12} radiator with the Cherenkov light going directly into a Photomultiplier tube array. The gas tight holding structure, electronics, cabling, monitoring and testing are also included.

WBS 1.4 Electromagnetic Calorimeter

This level 2 summary element consists of a gas tight structure that holds ~10,000 $PbWO_4$ crystals, each connected to a Photo-multiplier tube and readout electronics. The cabling and testing of the system are also included.

WBS 1.5 Muon Detector
This level 2 summary element provides wire chamber based detectors arrayed among the toroid magnets that detect the presence of muons and provide an alternate trigger based on opposite signed dimuons. The gas system, holding scheme, electronics and testing are also included.

WBS 1.6 Forward Straw Tracker
This level 2 summary element provides for tracking charged particles in all but the inner regions of the spectrometer where the Forward Silicon System provides this function. WBS 1.6 includes wire chambers constructed with outer plastic elements surrounding each wire, hence "straws" the associated electronics, cabling and gas system. The system also provides some support for the inner Silicon Tracker. Testing is included.

WBS 1.7 Forward Silicon Tracker
This level 2 summary element includes single sided silicon strip detectors the associated electronics, cabling and a cooling system. Testing is included.

WBS 1.8 Trigger System
This level 2 summary element includes specialized electronics and computing that takes data from the pixel detector (primary) or the muon system (alternate) and makes a decision on whether or not to keep the raw data in a given interaction for further processing. It includes all cabling, software and testing.

WBS 1.9 Data Acquisition System
This level 2 summary element includes: hardware and software necessary to load data into the trigger and save it for further processing if required by the trigger; hardware and software to record the data to archival storage; and hardware and software to control and monitor the experiment. It includes cabling, computing, software and testing.

WBS 1.10 Integration and Installation
This level 2 summary element contains planning, infrastructure, transportation to C0, and all things necessary to install the experiment that are not included elsewhere.

WBS 2 C0 Interaction Region
This Level 1 summary element consists of all elements of the BTeV Project required to implement a high luminosity (low beta) interaction region in C0

to provide the luminosity required by BTeV. It also includes reconfiguration of C0 into a standard straight section to support BTeV parasitic commissioning, also known as Test Mode.

WBS 3 C0 Outfitting

This Level 1 summary element consists of outfitting the C0 assembly hall with a three level counting room, and providing power and services.

WBS 3.1 C0 Outfitting, phase 1

This Level 2 summary element consists of architectural and structural completion of counting room, and primary power for magnet testing.

WBS 3.2 C0 Outfitting, phase 2

This Level 2 summary element consists of mechanical and electrical distribution throughout C0 building

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WBS 3.3 C0 Sector High Voltage

This Level 2 summary element consists of installs new high voltage feeders.

WBS 3.4 Pre-procurement Items

This Level 2 summary element consists of buying cables switches and transformers for contractors to install.

WBS 4 Project Management

This Level 1 summary element consists of reviews, reports, site visits, local supervision, running technical board meetings, standards preparation, tracking and analysis, schedule preparation tracking and analysis, change control. It also includes procurement of relevant software and computers and running the project office.

5 RESOURCE PLAN

The planned funding profile for the BTeV Project can be found in Table 1. It includes all sources of funding including those from DOE through Fermilab, US BTeV collaborators supported by DOE and NSF, Italian collaborators supported by INFN funding, and Russian and Chinese collaborators. All foreign sources are in-kind contributions applied toward projects from non-US collaborators. U.S. Universities support is from in-kind support of engineering and other technical personnel.

Table 1: Planned funding profile for the BTeV Project.

Planned Funding (AY dollars in thousands)						
Source	**FY05**	**FY06**	**FY07**	**FY08**	**FY09**	**Total**
DOE Equipment	6,750	39,000	49,000	49,400	42,500	186,650
DOE R&D	4,240	2,200	0	0	0	6,440
DOE Operations	2,100	0	2,200	2,300	2,400	9,000
INFN [1]						
NSF[2]						
Forward funding	7,500	0	0	0	-7,500	0
Total Funding	**20,590**	**41,200**	**51,200**	**51,700**	**37,400**	**202,100**

6 TECHNICAL, SCHEDULE, AND COST BASELINE

6.1 Technical Baseline and Technical Definition of Project Completion

The technical baseline for the Project is described in the BTeV Technical Design Report. The technical definition of Completion for each BTeV subprojects is shown in Table 2. Project Completion is based upon full installation of detector components in the Collision Hall, complete installation of elements of the trigger and data acquisition system in the counting room, integration of all components, and checkout with source, pulsers and/or cosmic rays to verify the functionality of the BTeV detector components prior to operation with colliding beam; full installation and operation of all beamline elements at design power and successful operation of all devices, instrumentation, controls, and interlocks from the Accelerator Division Control System; and acceptance of all work performed for C0 Outfitting in accordance with the conditions set forth in the corresponding contracts.

[1] Funding is under discussion with INFN and could result in in-kind contributions offsetting as much as $10M of costs to DOE

[2] Funding is under discussion with NSF and could result in contributions that would offset as much as $16M of costs to DOE

Table 2. Technical definition of Project Completion for WBS 1.0, 2.0, and 3.0

Subsystem	Technical Definition of Completion
1.1 Magnets, Toroids, Beam pipes	Operation of all magnets in C0 IR at design current and verification of design field, vacuum pumped down to acceptable level
1.2 Silicon Detector	System test with successful readout of 60 stations.
1.3 RICH	System test with 95% all sensors operational successful. Observation of Rings from Cosmic rays or beam spray
1.4 EMCAL	System test with all 95% of all crystals successful. Observation of signals from pulsers on each channel.
1.5 Muon Detector	System test with all planes at voltage and successfully read out. Observation of signals from cosmic rays.
1.6 Forward Straw Tracker	System test with all planes at voltage and successfully read out. Observation of signals from cosmic rays.
1.7 Forward Microstrip Tracker	System test with all planes at depletion voltage and noise observed on all channels.
1.8 Trigger	Complete system installed and interfaced to pixel and muon systems and meeting requirements based on checkout with simulated data
1.9 Data Acquisition	Readout of all detectors and observation of either noise signals, pulser signals, or cosmic rays depending on the detector
1.10 Integration	Complete installation of detector, with all components having all services required to operate, and all detectors interfaced to data acquisition and slow controls
2.0 C0 Interaction Region	All magnet and ES separator components surveyed on beam and operating at full power. All instrumentation and control hardware and software operational/
3.0 C0 Outfitting	All building and Electrical work complete and accepted as meeting the terms specified in the contracts

6.2 Project Schedule

A comprehensive schedule of work to design, construct, assemble, and commission the BTeV detector is maintained to facilitate management of the Project. It is comprised of detailed schedules for the development of each subsystem in the project and includes the resources (cost, manpower) required for each step. Based on these details, an overview of the project has been fashioned, complete with cost and manpower needs as a function of time and a series of milestones spread throughout the project. The WBS structure is defined through this schedule.

6.2.1 Schedule Methodology

The schedule is assembled using the computer program OpenPlan, created by the WELCOM Corporation. Subproject managers are responsible for the generation and maintenance of the schedules for their subsystems, in collaboration with the BTeV Project Office.

The schedule is built of tasks of various durations and milestones that are linked to describe the flow and interdependency of the work. The manpower required to complete each task is specified. Separate allocations are made for various types of technical personnel – including mechanical and electrical engineers, designer/drafters and technicians, as well as physicists, both for Fermilab and non-Fermilab employers. Thus, profiles in time of various work groups are readily obtained to aid in the establishment of manpower requirements and the allocation of personnel as the Project evolves. By entering the average hourly labor cost for each type of manpower, labor cost profiles are extracted for each work group as well as the total labor cost for each subproject and for the entire Project.

The M&S funds needed to complete each task are determined and assigned directly to the tasks in the schedule. Cost plans for each subproject and for the full project are then derived. Using this information, a consistent and viable work plan is established by making appropriate adjustments to the schedule to yield an overall cost plan that matches the profile of funds available from the Laboratory and other sources, and a manpower plan that can be supported by the Laboratory. We note that for all M&S and labor estimates, a detailed Basis of Estimate (BoE) is provided that describes the foundation of and justification for the resources assigned to each task in the schedule. Cost Books have been prepared that provide the source documentation (quotes, invoices, etc.) and supplementary information used in preparing the BoE.

The scheduling program identifies the critical path (or paths) to completion of the Project. This feature calls attention to those tasks that have no 'float' or slack and that must therefore be carefully monitored to prevent delay in project completion. Knowledge of the critical path facilitates changes to optimize the work and to hasten completion

6.2.2 Project Schedule Milestones

A baseline schedule that is consistent with the available funding and manpower resources has been assembled. The schedule is monitored by the Subproject Managers and the Project Manager. A hierarchical set of milestones have been established to track progress in the Project. At the lowest level (Level 5), a comprehensive set of milestones are distributed throughout the duration of each subproject, with the Subproject Managers holding change control authority for the Level 5 milestones. A subset of the Level 5 milestones is selected to serve as Level 4 milestones; the Project Manager monitors and holds change control authority for the Level 4 milestones. The Level 3 milestones are derived from a subset of Level 4 milestones; the Deputy Director monitors and holds change control authority for the Level 3 milestones. These “Director’s Milestones” are listed in Table 6 below. The Level 2 milestones are derived from a subset of the Level 3 milestones; the DOE BTeV Project Manager monitors and holds change control authority for Level 2 milestones. These are shown in Table 5. The Level 1 milestones are derived from these. The Acquisition Executive monitors and holds change control authority for the Level 1 milestones as described in the PEP. The Level 1 milestones are listed in Table 4 below. The Level 0 milestones represent the Critical Decisions for the project; the DOE Deputy Secretary monitors and holds change control authority for the Level 0 milestones as described in the PEP. The Level 0 milestones are listed in Table 3 below.

Table 3. CD and Level 0 milestones for the BTeV Project.

	Description	Baseline Date
	CD-0: Approve Mission Need	2nd Quarter FY04
	CD-1: Approve Alternative Selection and Cost Range	3rd Quarter FY04
	CD-2: Approve Performance Baseline	1st Quarter FY05
	CD-3a: Approve Limited Construction	1st Quarter FY05
	CD-3b: Approve Start of Construction	3rd Quarter FY05
0.1	CD-4: Approve Start of Operations or Project Closeout	1st Quarter FY11

Table 4. Level 1 milestones for the BTeV Project.

No.	WBS	Milestone	Internal Date	Formal Date
1.1	2.0	Purchase Order awarded for superconducting wire	Jul. '05	Sep. '05
1.2	3.0	Beneficial occupancy of lower level and upper staging area of C0	Feb. '06	Jul. '06
1.3	1.1	Vertex Magnet installed in C0 and powered	Oct. '06	Aug. '07
1.4	1.2	PO awarded for production pixel hybridization	Feb. '07	Jun. '07
1.5	1.4	20% of PWO Crystals accepted	Nov. '07	Mar. '08
1.6	1.2	Pixel System assembled and tested at SiDet, ready to ship to C0	Mar. '09	Aug '09
1.7	2.0	IR Components complete, installed and under power	Oct. '09	Feb. '10
1.8	1.0,1.10	Detector complete and ready for commissioning with beam	Oct. '09	Feb. '10

Table 5. Level Milestones for the BTeV Project. The milestones shown in red have corresponding Level 1milestones listed in Table 4 above(!!!!!replace with real table).

No.	WBS	Milestone	Internal Date	Formal Date
2.1	1.1	Vertex Magnet installed in C0 and powered	Oct. '06	Aug. '07
2.2	1.2	Purchase order placed for pixel readout chip	Jul. '06	
2.3	1.2	Purchase order placed for pixel detector hybridization	Feb. '07	
2.4	1.2	PO awarded for pixel sensors	Feb. '06	Jun. '07
2.5	1.2	Pixel System assembled and tested at SiDet, ready to install in C0	Mar. '09	Aug. '09
2.6	1.3	Rich Tank Installed in C0	Sep. '08	
2.7	1.3	MAPMT PO awarded	Oct. '05	
2.8	1.4	QIE PO awarded		
2.9	1.4	20% of PWO Crystals accepted	Nov. '07	Mar.'08
2.10	1.4	80% of PWO Crystals accepted		
2.11	1.4	EMCAL Support structure (partially loaded) installed		
2.12	1.5	Beginning of octant production	May '07	
2.13	1.6	ASDQ PO awarded	Oct. '04	
2.14	1.6	Station 1 ready for installation in C0	Oct. '08	
2.15	1.7	Readout IC approved for production		
2.16	1.7	First FSIL station ready to be installed in C0	Nov '08	
2.17	1.8	Trigger pilot system tested		
2.18	1.8	First production release of Level 2/3 Trigger software	Jul. '07	
2.19	1.9	Data Combiner Board pre-production units tested and approved	Jul. '07	
2.20	1.9	Multinode release of Data Acquisition RCS package	Aug.'08	
2.21	2.0	Purchase Order awarded for superconducting wire	Jul. '05	Sep. '05
2.22	2.0	IR Components complete and ready to install	Oct. '09	
2.23	3.0	C0 Outfitting Start Construction		
2.24	3.0	Beneficial occupancy of lower level and upper staging area of C0	Feb. '06	Jul. '06
2.25	3.0	C0 Outfitting construction complete		
2.26	2.0	IR Components complete, installed and under power	Oct. '09	Feb. '10
2.27	1.0, 1.10	Detector complete and ready for commissioning with beam	Oct. '09	Feb. '10

Table 6: Level 3 (Fermilab Director's) Milestones

No	WBS	Milestone	Internal Date	Formal Date
	1.1	Magnets, Toroids, Beam pipes		
3.1		Vertex Magnet parts complete	Feb '06	
3.2		Vertex magnet ready for installation	Jun '06	
3.3		Toroid parts acquisition complete	Apr '06	
3.4		South Toroid ready for installation	Jul '06	
3.5		North Toroid ready for installation		
3.6		Beam pipe rework begins		
3.7		RICH beam pipe ready for installation	May '08	
3.8		Forward tracking Beam pipe ready for installation		
	1.2	Pixel Detector		
3.9		Contract placed for pixel sensors	Feb. '06	
3.10		Contract placed for pixel readout chip	Jul. '06	
3.11		Contract placed for pixel detector hybridization	Feb. '07	
3.12		10% system assembled and ready to ship to C0	Feb. '07	
3.13		Vacuum system designed approved	May '07	
3.14		Final detector assembly started	Nov. '07	
3.15		Production pixel module completed	May '08	
3.16		System fully assembled and tested at SiDet, ready to ship to C0	Feb. '09	
	1.3	RICH		
3.17		Start MAPMT Production	Oct. '05	
3.18		All MAPMTs delivered	Jun. '08	
3.19		MAPMT Hybrid (VA-BTeV) Production started	Oct. '07	
3.20		MAPMT Hybrid Production completed	Aug. '08	
3.21		Mirror Segment Construction Complete	Dec. '06	
3.22		RICH Detector completely installed in C0	Aug. '09	
3.23		PMTs for Liquid Radiator Procurement complete	Apr. '07	
3.24		Liquid radiator assembly completed	Mar. '06	
	1.4	EMCAL		
3.25		First EMCAL Crystal Purchase Order awarded	Nov '05	
3.26		EMCAL Crystals Procurement complete	Jul '09	
3.27		ADC card checkout complete	Feb '08	
3.28		QIE Packaged parts are tested	Feb '05	
3.29		PMT Procurement complete	Sep '08	
3.30		Assembly of EMCAL complete	Aug '09	

	1.5	Muon detector		
3.31		End of Octant Pre-production	Jun. ‘06	
3.32		Complete 10% of Production Planks	Sep. ‘06	
3.33		Beginning Octant Production	May ‘07	
3.34		ASDQ procurement complete	Sep. ‘05	
3.35		Complete 20% of Production front end boards	Jun. ‘07	
3.36		First Muon Station Installation Completed	Aug. ‘07	
3.37		Muon Detector Complete	Sep. ‘09	
	1.6	Forward Straw Tracker		
3.38		ASDQ chip procurement initiated	Oct. ‘04	
3.39		ASDQ procurement complete	Sep. ‘05	
3.40		Preparation site functional	Mar. ‘06	
3.41		Production/assembly sites functional	Feb. ‘07	
3.42		Station 1 ready for installation in C0	Oct. ‘08	
3.43		Station 7 ready for installation in C0	Mar. ‘09	
	1.7	Forward Silicon Tracker		
3.44		Sensor accepted for full production	Feb ‘07	
3.45		Production sensors received and tested	Jul ‘08	
3.46		Readout IC approved for production	Oct ‘06	
3.48		Production Ics Received tested and thinned	Sep ‘07	
3.49		Hybrids approved for production	Feb ‘07	
3.50		Hybrids complete and tested	Mar ‘06	
3.51		Station support procurement complete	Sep ‘08	
3.52		Ladder production 100% Complete	Oct ‘08	
3.53		First FSIL station ready to be installed in C0	Nov ‘08	
3.54		Last FSIL station ready to be installed in C0	Dec ‘08	
	1.8	Trigger		
3.55		Begin L1 2-highway pixel processor and segment tracker production	Nov ‘07	
3.56		End L1 2-highway pixel processor and segment tracker production	Dec ‘08	
3.57		Begin L1 2-highway farm production	Nov ‘07	
3.58		End L1 2-highway farm production	Feb ‘08	
3.59		Begin L2/3 farm worker node procurement	Dec ‘07	
3.60		Begin Level 3 software development	Oct ‘05	
3.61		Complete first production release of Level 2/3 software	Jul ‘07	
3.62		Complete trigger system and integration with DAQ	Sep ‘09	
	1.9	Data Acquisition System*		

3.63		Pre-production DCB units tested and approved	Jul '07	
3.64		Production DCB delivered and tested	Apr '09	
3.65		Production Level 1 Buffers delivered and tested	Jun '09	
3.66		Single node release of RCS package	May '07	
3.67		Data Acquisition software complete	Mar '09	
3.68		Calibration and Trigger database complete	Jul '08	
	1.10	Integration, Installation, and testing		
3.69		PO Placed for Production of HV Power supplies		
3.70		High Voltage Power Supplies Delivery Complete		
3.71		Vertex Magnet installed	Sep. '06	
		South Toroid installed	Aug. '06	
3.72		North Toroid Installed	Aug. '07	
3.73		Rich Tank Installed	Sep. '08	
3.74		EMCAL Support structure (partially loaded) installed	Aug. '08	
3.75		Trigger, Data Acquisition System installed		
3.76		All detectors and support systems installed	Oct. '09	
	2.0	C0 Interaction Region*		
3.77		Issue RFP for superconductor:	Oct '04	
3.78		Begin quadrupole production:	Jun '06	
3.79		Issue RFP for HTS leads:	Feb '05	
3.80		Issue RFP for corrector magnets:	May '05	
3.81		Initiate fabrication of spool assembly:	May '07	
3.82		Complete quadrupole fabrication and test:	Mar '09	
3.83		Complete spool assembly fabrication and test:	Jun '09	
	3.0	C0 Outfitting		
3.84		Start Construction		
3.85		Beneficial occupancy of lower level and upper staging area		
3.86		Collision Hall complete		
3.87		Assembly, Service Building Construction complete		
	4.0	Project Office		
3.88		Staffing complete	Oct. '04	
3.89		Effort reporting in place	Oct. '04	
3.90		First internal reviews conducted		
3.91		Begin monthly reports	Oct. '04	
3.92		Complete key standards and QA plans		

6.3 Manpower Requirements

The manpower requirements are extracted from the schedule and are given in Table 6 in units of person-years. The categories shown include all collaboration-wide physicist manpower (Physicist), technical manpower provided by collaborating institutions (Technical-University), and technical manpower provided by Fermilab (Technical-Fermilab). Note that physicist manpower is funded by non-Project sources and is not included in the Project cost.

Table 7: Staffing plan for physicist and technical manpower. Units are person-years

	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	Total
Physicist	56	89	84	76	37	342
Technical-University	11	25	22	16	11	85
Technical-Fermilab	30	61	64	61	36	252
BTeV Total	**97**	**175**	**170**	**153**	**84**	**679**

6.4 Project Cost

The cost estimate for the Project covers all Materials & Services (M&S) and Salaries, Wages and Fringe Benefits (SWF) costs for the Project. It does not include the operating costs for detector components after they are installed in the Collision Hall or counting room and commissioned without beam.

6.4.1 Cost Estimate

The M&S costs and labor resources are estimated at the lowest (task) level in the Project Schedule. Contingency for labor and M&S is also estimated at the task level based on the guidelines described in sections 0 and 0. The Project Manager is able to review the costs at any level of detail by examining the roll ups of tasks within a given class. The cost estimates provided by the Subproject Managers are reviewed by the Project Manager in consultation with any technical experts that are deemed necessary to evaluate the cost estimates. The costs in the schedule are given in FY`05 dollars. Appropriate overhead and escalation is done external to OpenPlan, within the COBRA accounting program that is used to compute earned value. It is foreseen that all project tracking and accounting will be done within the COBRA structure for the duration of the Project

6.4.2 M&S Contingency Estimation

There are two estimates of contingency made for the Project. One estimate is made by the WBS level 3 Subproject Managers at the lowest available level. It is based on detailed estimates of designs where available, and on the experience of the Subproject Managers and the engineering staff directly involved with the subsystem where a conceptual design exists. Guidelines for the estimation of the contingency have been provided, but may be overridden by the Subproject Managers in exceptional cases. The general guidelines for the contingency estimation for M&S are:

- 0% on items that have been completed,
- about 10-15% on items that have been ordered, but not delivered (this accommodates change orders, delivery costs, etc.),
- about 30-50% on items that can be readily estimated based on quotes for a detailed design,
- about 50-70% on items for which a detailed conceptual design exists, but which may vary due to scope changes such as channel count, and
- about 70-100% on items for which there does not yet exist a detailed conceptual design, but which is an item required for the Project.

In addition, the Project Manager constructs a "top-down" estimate of the contingency based on past experience, DOE guidelines, and the fiscal history of similar completed projects. The Project Manager makes the ultimate determination of the M&S contingency, taking his own estimate and that constructed by the lower level managers into consideration.

6.4.3 Labor Contingency Estimation

Contingency on labor estimates is handled in an analogous manner to those for M&S. One estimate is made by the WBS level 3 subproject managers at the lowest available level. The general guidelines for estimating contingency on labor are:

- For a complex project with a long learning curve, that % which the project can absorb efficiently. For software development, we set this at 25%.
- For project which is well-defined and effort has been quantified, 25% if there is no paid idle time or 50% if there is
- For a project with a time and motion type study 30-40%
- For a project which has been done before and has a reasonably good estimate based on actual time paid for - 15-25%
- For a project of uncertain labor requirements, 50%

These can be overridden in exceptional cases, and should be tailored to the time evolution of the project. For example, estimates for labor contingency may be augmented during peak production periods in order to adequately cover this labor-intensive portion of the Project.

The Project Manager makes the ultimate determination of the contingency on labor, taking his own estimate and that constructed by the lower level managers into consideration.

6.5 Cost Summary

The Total Estimated Cost (TEC) of the BTeV Project in AY dollars is $189.7M, including $50.2M in contingency. The Total Project Cost (TPC) for the BTeV Detector Project in AY dollars is $199.0M, including $52.7M in contingency. A breakdown of the Project Cost in AY dollars at WBS Level 2 is presented in Table 8. An obligation profile showing the anticipated obligations by fiscal year is extracted from the schedule. Table 9 shows the obligation profile for the Detector subproject at WBS Level 3 with contingency broken out from the subsystem costs.; the obligation profile for the CO IR subproject at WBS Level 2 with contingency broken out; the obligation profile for the C0 Outfitting with contingency broken out; and finally the obligation profile for the Project Office with contingency broken out. Table 10 shows the complete obligation profile for all three Level 1 subprojects combined.

Table 8. Project costs in AY dollars at WBS Level 2 for the BTeV Project.

WBS	Description	Base k$	Contingency k$	Contingency %	Total k$
1.1	Magnets, Toroids, Beampipes	1,853	458	25%	2,311
1.2	Pixel Detector	16,420	6,585	40%	23,006
1.3	RICH	12,275	4,643	36%	17,419
1.4	EMCAL	13,044	4,429	33%	17,374
1.5	Muon	3,992	1,393	35%	5,385
1.6	Forward Straw tracker	10,112	2,915	29%	13,028
1.7	Forward Silicon Tracker	7,944	2,700	34%	10,644
1.8	Trigger	13,177	5,467	41%	18,845
1.9	Event Readout and Control	13,267	4,528	34%	17,785
1.10	Installation, integration, commissioning	7,593	3,860	51%	11,453
1	COST BTeV Detector				
2	Cost C0 IR	27,490	10,725	39%	38,215
3	Cost C0 Conventional Construction	6,169	1,271	21%	7,440
4	BTeV Project Office	5,680	1,327	23%	7,007
	TOTAL ESTIMATED COST	139,517	50,202	36%	189,719
	Total BTeV "other project" costs	6,706	2,535	38%	9,241
	TOTAL PROJECT COST	146,223	52,737	36%	198,960

Table 9. Obligation profile for the BTeV Project

Obligation Profile (AY dollars in thousands)						
Source	**FY05**	**FY06**	**FY07**	**FY08**	**FY09**	**Total**
Magnets, Toroids, & Beampipes	155	1120	345	233	0	1853
Pixel Detector	1398	4655	5617	4134	616	16420
RICH	504	3113	4954	3733	471	12775
EMCAL	380	2632	4261	4290	1481	13044
Muon Detector	454	1346	1692	414	86	3992
Forward Straw Tracker	1077	3405	2666	2252	713	10112
Forward Microstrip Tracker	776	1922	2026	3114	104	7944
Trigger	471	1475	1899	3475	5858	13177
Data Acquisition	307	2136	2910	4221	3692	13267
Integration and Installation	116	775	1595	2940	2167	7594
C0 IR	5443	7355	6479	5253	2959	27490
C0 Outfitting	1571	2410	2188	0	0	6168
Project Office	920	1187	1239	1188	1146	5680
Subtotal (Base cost)	**13,572**	**33,531**	**37,879**	**35,248**	**19,294**	**139518**
Contingency	**4228**	**11449**	**13518**	**12885**	**8121**	**50202**
Total Subproject Cost	**17800**	**44980**	**51391**	**48134**	**27415**	**189720**

Table 10. Obligation profile for entire BTeV project

Obligation Profile (AY dollars in thousands)						
Source	**FY05**	**FY06**	**FY07**	**FY08**	**FY09**	**Total**
BTeV Detector	5638	22578	27966	28807	15189	10178
C0 IR	5443	7335	6479	5253	2959	27469
C0 Outfitting	1571	2410	2188	0	0	6169
Project Office	920	1187	1239	1188	1146	5680
Sub Total	13572	33530	37879	35248	19294	139523
Contingency	4228	11449	13520	12886	8121	50204
Total Project Cost	**17800**	**44979**	**51399**	**48134**	**27415**	**189727**

7 CHANGE CONTROL THRESHOLDS

Any change to the Project that does not alter the scope of the Project as defined above does not require a new proposal to be submitted to the Laboratory. Although the scope of the project is not affected, changes resulting in cost variations, changes of personnel assignments, or schedule impact are considered changes to the project plan that may require authorization to implement.

7.1 Change Control Procedures

Formal change control procedures will be used to track technical, schedule, and cost changes in the Project. Each such change requires the preparation of a Change Request form. Each Change Request will be reviewed by the Project Manager. The BTeV PMG will function as a Change Control Board for the project. Subject to the change control levels described below, the Change Request may be forwarded to the BTeV PMG for approval by the Deputy Director. The BTeV Project Manager will maintain current records of all Change Requests and their disposition

7.2Technical Change Control Levels

Minor technical changes consistent with the baseline technical design must be approved by the Subproject Manager.

Major technical changes that are a significant departure from the baseline technical design must be approved by the Project Manager.

Technical changes that affect ES&H requirements, impact accelerator systems, or changes in scope that affect physics capabilities require a Change Request be submitted for consideration by the BTeV PMG and approved by the Deputy Director.

7.3 Schedule Change Control Levels

Changes that result in the delay of a Level 5 milestone by more than a month must be approved by the Subproject Manager.

Changes that result in the delay of a Level 4 milestone by more than a month must be approved by the Project Manager.

Changes that result in the delay of Level 3 Director's Milestones require a Change Request be submitted for consideration by the BTeV PMG and approved by the Deputy Director and the DOE BTeV Detector Project Manager. The response to such a Change Request may be to initiate a plan to reallocate resources to recover the schedule, a plan to stage or descope the detector, or rescheduling of the milestone.

7.4 Cost Change Control Levels

Changes to the cost of a single item exceeding $10K must be approved by the Subproject Manager.

Changes to the cost of a single item exceeding $50K or a 10% increase in the Subsystem base cost during the previous 12 months must be approved by the Project Manager.

Changes in the cost of a single item exceeding $250K or a $1.5M increase in the project base cost during the previous 12 months require a Change Request be submitted for consideration by the BTeV Project Director to the BTeV PMG and approved by the Deputy Director.

7.5 Change Control Summary

Table 11 summarizes the Fermilab change control thresholds and responsibilities. Table 12 summarizes the DOE change control thresholds and responsibilities described in the PEP. Figure 2 shows a sample Change Request form.

Table 11. Fermilab technical, schedule, and cost baseline control levels.

	Fermilab Deputy Director	**BTeV Project Manager**	**Subproject Manager**
Technical	Changes that affect ES&H requirements or impact accelerator systems. Out-of-scope changes to upgrade physics capabilities.	Major technical changes that are significant departures from the baseline technical design.	Minor technical changes that are consistent with the baseline technical design.
Schedule	Any change that results in the delay of a Level 2 Director's milestone.	Any change that results in the delay of a Level 3 milestone by more than one month.	Any change that results in the delay of a Level 4 milestone by more than one month
Cost	Increase in the cost of a single item by more than $250K. Increase in the Project base cost exceeding $1.5M during the previous 12 months.	Increase in the cost of a single item by more than $50K. Increase in a subsystem base cost exceeding 10% during the previous 12 months.	Increase in the cost of a single item by less than $10K.

Table 12:. DOE technical, schedule, and cost baseline control levels from the PEP.

	Deputy Secretary (Level 0)	**Acquisition Executive (Level 1)**	**DOE BTeV Project Manager (Level 2)**
Technical	Decrease in scope to maintain cost.	Changes to scope that affect mission need.	
Schedule	Any change to level 0 milestones.	Any change to level 1 milestones.	Any change to level 2 milestones (see PMPs).
Cost	Any increase in TEC (TPC will be controlled via the PMPs).		Any use of contingency that would take the contingency as a percentage of ETC below 25%.

1) DATE:	2) WBS NUMBER:	3) ORIGINATOR:
4) TITLE OF CR & MASTER LOG NUMBER:		

5) WBS DESCRIPTION OF PRIMARY AFFECTED TASKS:

6) TECHNICAL DESCRIPTION AND PRIMARY MOTIVATION OF CHANGE (technical, cost, schedule, or other; include interfaces with other areas and use attachments, as necessary):

7) ASSESSMENT OF COST IMPACT:

	--------Before CR--------		--------After CR--------		-----------Delta (+/-)-----------			Total Cost
WBS	M&S	Labor	M&S	Labor	M&S	Labor	G&A/Esc	Increase*

*- Final escalation to be calculated by COBRA.

BTeV Budget Officer Concurrence _________ Initial / Date Input to Cost Estimate Complete _____Initial

8) ASSESSMENT OF SCHEDULE IMPACT AND LIST OF AFFECTED MILESTONES:

		---Before CR---	---After CR---	---Delta (+/-)---
Milestone	Level	Date	Date	

BTeV Schedule Manager Concurrence _________ Initial / Date Input to Schedule Complete _____Initial

9) SECONDARY IMPACT: ES&H AND OTHER COMMENTS:

10) APPROVALS

BTeV Project Director ____ Signature

DateBTeV Project Manager ____ Signature / Date

BTeV Level 2 Manager ____ Signature / Date

BTeV Level 3 Manager ____ Signature / Date

11) FERMILAB DIRECTOR DISPOSITION

O Approved O Disapproved ______________________________

Signature/Date

12) DOE DISPOSITION

O Approved O Disapproved ______________________________

Signature/Date

Figure 2. Sample Change Request form.

8 RISK MANAGEMENT ASSESSMENT

Detector construction projects are well within the experience and expertise of the BTeV collaboration. Every effort has been made to specify these projects in a manner that reduces the risk to an acceptably low level. Several steps will be taken to assure that the risk to this project is low. A general discussion of risk may be found in Section 7 of the Acquisition Strategy Plan for the BTeV Project (ASP).

8.1 Technical Risk

Preparation of clear and concise specifications, judicious determination of subcontractor responsibility and approval of proposed lower tier sub-subcontractors, and implementation of QA provisions will minimize technical risk. Projects have been designed to further minimize technical risk by exploiting previous experience to the greatest extent possible, and minimizing exposure to single vendor failures.

Making deliberately conservative design choices, where possible, and carrying out extensive detector R&D where new technologies are involved has minimized technical risk throughout the BTeV Detector Project. Use of single sided sensors for the forward microstrip tracker, extensive R&D on the silicon pixel detector and the RICH readout, use of a switch based on commercial off-the-shelf components in the data acquisition system, reduction in component variety, and common integrated circuit technologies wherever possible will reduce risk. In all cases, the expertise of personnel involved in the design and implementation of previous versions of BTeV systems have been exploited to the fullest possible extent. Moreover, institutional commitments have been carefully crafted within the subprojects in order to help ensure timely and successful completion of the Project.

8.2 Cost Risk

Use of fixed-price subcontracts and competition will be maximized to reduce cost risk.

8.3 Schedule Risk

As outlined in Section 7.3 of the ASP, schedule risk will be minimized via:

- Aggressive R&D, including bench testing and beam testing
- Realistic planning,
- Verification of subcontractor's credit and capacity during evaluation,
- Close surveillance of subcontractor performance,
- Advance expediting, and
- Incremental awards to multiple subcontractors when necessary to assure total quantity or required delivery.

Incentive subcontracts, such as fixed-price with incentive, will be considered when a reasonably firm basis for pricing does not exist or the nature of the requirement is such that the subcontractor's assumption of a degree of cost risk will provide a positive profit incentive for effective cost and/or schedule control and performance.

In addition, the Project will be tracked monthly, with schedule changes carefully monitored and approved through a change control process overseen by a combination of the Project Manager, the Laboratory Directorate, and DOE (see section 8 of this document).

8.4 Risk Analysis

Risk to the project will be evaluated by following a method outlined in "A Guide to the Project Management Body of Knowledge". Two risk-related quantities are estimated for each significant element of the project, an impact factor, and a risk probability. The impact factors are described in Table 13.

Table 13. Risk impact factors for the BTeV Detector Project.

Evaluating Impact of a Risk on Major Project Objectives					
Project Objective	**Very low 0.05**	**Low 0.1**	**Moderate 0.2**	**High 0.4**	**Very high 0.8**
Cost	Insignificant cost increase	< 5% Cost increase	5-10% Cost increase	10-20% Cost increase	> 20% Cost increase
Schedule	Insignificant schedule slippage	Schedule slippage < 5%	Overall Project slippage 5-10%	Overall Project slippage 10-20%	Overall Project slippage > 20%
Scope	Scope decrease barely noticeable	Minor areas of scope affected	Major areas of scope affected	Project scope reduction unacceptable for physics objectives	Scope of project effectively useless for mission
Technical	Technical degradation of project barely noticeable	Technical performance of final product minimally affected	Technical performance of final product moderately affected	Degradation of technical performance unacceptable for physics objectives	Technical performance of end item effectively useless for mission

For each WBS level 4 item within the project, an estimate will be made on the nature of the risk this item presents to the project as a whole. The impact for each of the four categories given in the table will be considered. The probability of occurrence (cost overrun, schedule slippage, etc.) will also be estimated. The product of these two quantities is the risk factor. Mitigation strategies will be considered for any high-risk items in the project, currently estimated as a risk factor of 0.18 or greater.

9 PROJECT CONTROLS SYSTEM

9.1 Introduction

This chapter summarizes the management systems that the Project will use to monitor the cost and schedule performance and the technical accomplishments of the Project. The significant interfaces that exist among the various management systems are noted in the individual narrative descriptions below. Although these systems are described separately they are mutually supportive and will be employed in an integrated manner in order to achieve the project objectives. As conditions change during the evolution of the project, the management systems will be modified appropriately so as to remain responsive to the needs for project control and reporting. Consequently, while the policy and objectives of each management system will remain fixed, the methods, techniques, and procedures that will be employed by the Project may change as conditions dictate, over the life of the project.

The Work Authorization and Contingency Management System and the Project Control System described in this chapter define the management and control procedures required by the Laboratory.

9.2 Guidelines and Policies

The Contingency Management System and the Project Control System employed by the Project will be consistent with the Fermilab "Project Control System Guidelines", dated May 1, 1994.

The following policies are applicable for the BTeV Detector Project:

- All Project work is organized in accordance with the WBS.
- Formal (and informal) reviews by experts are used to establish baseline specifications and designs.
- Established cost, schedule, and technical baselines are used for measuring project performance. Technical baselines are maintained in the Technical Design Reports describing the current design implementation for each system included in the scope of the Project.
- Changes to the approved cost, schedule and technical baselines proceed via a Change Request process described below.
- A project management system that features performance measurement based on cost accounting and scheduling is used to control the project and to provide forecast and feedback information to management. In particular, Earned Value will be calculated via the cost accounting tool COBRA, which uses as input the OpenPlan BTeV Project schedule.
- The decision-making apparatus includes regular meetings between the Project Manager and the Subproject Managers. These meetings help to identify and resolve interface issues within the project.
- Quality assurance, safety analysis and review, and environmental assessment are integral parts of the Work Authorization and Project Control.

9.3 Work Authorization and Contingency Management

Funds will be made available by the Director to the Project on an annual basis following the receipt of the Initial Financial Plan from DOE. These funds will correspond to a financial plan and a funding profile to project completion as determined by the Director. The funding profile will include contingency in each year of the project.

Work packages will be established by the Fermilab Budget Office following the WBS structure. The accumulation of M&S costs in these accounts will be initiated through purchase requisitions originating with the engineering and scientific staff assigned to the various subsystems. Signature authority levels will be provided to the Fermilab Business Services Section by the Project Director to assure that only authorized work is initiated.

At any time, the project contingency is the difference between the project Total Estimated Cost (TEC) and the Estimate at Completion (EAC). The Project Director will hold the contingency and allocate it subject to the Project Control System described below.

The principles of contingency management that the Project will follow are as follows:

- The cost estimate for each subsystem will include contingency funds based on an assessment by the preparer, in conjunction with the PM, of uncertainties and risks associated with the budgeted cost;
- The actual expenditure of contingency will be reflected in a new EAC to be updated every six months;
- The Deputy Director will approve all Change Requests that will require utilization of contingency, subject to the thresholds levels below;
- All changes will be tracked with approved Change Requests and a record of all Change Requests will be maintained by the Project;
- Each fiscal year, the Project Director will assign the contingency available in that year within the following guidelines:

    - The Project Manager may adjust the estimated cost of any WBS level 2 subproject by as much as $100K, as long as the Project TEC is not exceeded. If the change exceeds $100K, the Change Request must be approved by the Deputy Director;

    - The use of contingency above the amount budgeted for the year requires that a Change Request be approved by the Deputy.

- All changes from baseline cost shall be traceable.

9.4 Baseline Development

Baseline development includes management actions necessary to define project scope and responsibilities, establish baselines, and plan the project. Each subproject prepares a formal cost estimate and schedule. The subprojects all have defined Work Breakdown

Structures (WBS) which are detailed subsets of the WBS, below level 2. In addition, technical specifications for each subproject are contained in the Technical Design Reports The BTeV Detector Technical Design Report includes detailed technical descriptions of all detector systems, the trigger and data acquisition systems, integration and installation, and pre-beam commissioning. The C0 Interaction Region Technical Design Report describes all aspects of the design and implementation of the high luminosity IR for C0. The C0 Outfitting Technical Design Report describes the design and implementation of work to provide the facilities required in C0 to support the BTeV experiment and the IR.

9.5 Project Performance Measurement

Project Performance includes management actions after work commences that are necessary to monitor project status, report and analyze performance and available resources, and manage risk. Project performance aspects of the Project Control System consist of the following:

9.5.1 Funds Management

The detailed obligation plan for each WBS item is derived from the baseline schedule for the project that is funded at a rate consistent with the profile of funds from the Laboratory and other sources. This top-down obligation plan is adjusted by Project Management as appropriate to reflect changes in the Laboratory funding profile.

9.5.2 Accounting

A record of all M&S obligations associated with individual WBS elements is maintained in the Project financial system for tracking purposes. Each obligation is identified with the corresponding cost account, thereby enabling comparison of obligations with the Cost Estimate at that level. Monthly tracking reports are produced that show all purchasing activity at the cost account level in each subproject. For each item, as well as roll-ups to higher levels, the cost estimate, current-year allocation, year-to-date and project-to-date obligations and balances are displayed.

All BTeV Project M&S transactions are also associated with Fermilab work packages, generally at WBS level 5 or below. The Fermilab financial system is used to track and account for all obligations and subsequent costs at level 4 and above. Monthly accounting reports depict obligation and cost details and summaries for all work packages or WBS categories at and above level 4. The cost of labor in each WBS level 2 category in the BTeV Project is captured by reporting the fraction of effort of each individual involved in the work and transferring the salary cost to the corresponding budget code.

The financial system accommodates the allocation of direct costs collected from a single point to multiple control accounts. This is accomplished through split coding. The split codes are tracked through the work packages in question and are reflected in the monthly reports.

9.5.3 Performance Measurement and Analysis

The principle functions of performance measurement and analysis are to identify, quantify, analyze and rectify significant deviation from the plan as early as possible. Earned-value reporting will be accomplished through the use of the COBRA software package.

9.5.4 Schedule Variance

At the end of each month, the detailed schedule for each subproject is examined for variances from the baseline schedule. This is accomplished by updating the 'actual' schedule on the basis of work performed in the period, and comparing the actual schedule to the baseline schedule. An extensive set of milestones for each subproject is also monitored. This is performed by the WBS Level 2 and Level 3 Managers, and submitted to the Project Management for examination and review.

Changes that have a significant impact on the project, either by delaying completion or by affecting the cost or manpower plan of the project, are identified for further analysis. A plan to rectify the problem is developed that may include:

- alteration of the schedule to optimize the work and reduce the delay,
- allocation of additional resources (funds or manpower) to shorten the time required to perform given tasks.

Any change that would alter the schedule, cost or personnel resources of work to be performed is subject to the controls described below.

9.5.5 Cost Variance

In approving a purchase requisition, the WBS level 2 managers will compare the proposed obligation with the balances remaining for that item and its parents at higher levels. If the obligation does not exceed the estimated cost, the manager may approve the requisition directly. However, if the obligation would require use of contingency on that item or at a higher level, the manager must formulate a plan to fund the item and attach the details to the requisition for approval by the Project Manager. In this fashion, use of contingency is approved prior to incurring the obligation. Cost variances that exceed the established thresholds are formally reported as provided below.

Each month, obligation performance is determined by comparing obligations to date with budgeted or allocated costs to date as indicated by the obligation-loaded schedule.

9.5.6 Resource Variance

On a monthly basis, the available funds and manpower resources are compared with those required in the schedule to identify shortfalls that could lead to schedule and/or cost variances. Any such variances will be brought to the attention of the BTeV PMG.

9.6 Change Management

Change management includes the actions necessary to ensure adequate control of project baselines, including the performance measurement baseline. Details regarding change control at DOE Levels 0 and 1 are contained in Section 6 of the PEP. Change Management aspects of the Project Control System consists of the following:

9.6.1 Out-of-Scope Changes

An out-of-scope change is a proposed change to the scope of the Laboratory-approved Project that would alter the physics capabilities of the detector in a major way or introduce a new detector system. The 'scope' of the project includes the design, construction and installation of the collection of systems or improvements to systems that have been granted Stage I approval by the Director. The scope of the project is defined by the proposal document that includes content equivalent to a Technical Design Report. Each individual system or an improvement to a system has an impact on the physics capability of the Project as a whole. This physics capability is also defined in the proposal. The scope of the project as an aggregate determines the physics capabilities of the upgraded detector.

Any out-of-scope change must be initiated by a formal proposal by the Spokespersons to the Director for consideration. In response to such a proposal, the Director may seek the advice of the Fermilab Physics Advisory Committee, the BTeV PMG and/or a Director's Review. Such a proposal may be granted Stage I approval, deferred for further clarification of the physics potential, technique, cost and/or schedule, or it may be rejected.

9.6.2 In-Scope Changes

Any change to the Project that does not alter the scope of the Project as defined above does not require a new proposal to be submitted to the Laboratory. Although the scope of the project is not affected, changes resulting in cost variations, changes of personnel assignments or schedule impact are considered in-scope changes. The change management for in-scope changes is fully described above on the mechanism for baseline change control.

9.7 Reporting and Review

9.7.1 Monthly Progress Reports

The Project provides reports on a regular basis to Fermilab and DOE management. The objective of the reporting is to provide for the collection and integration of essential technical, cost, schedule and performance data into reports to aid in the monitoring and management of the Project.

All WBS Level 2 Managers submit monthly written reports to the Project Manager detailing specific progress on the pertinent subsystems. These reports summarize the activities of the previous month, describe activities planned for the upcoming month, and include comments and concerns. They are collected and summarized in a corresponding monthly report submitted to the Particle Physics Division Head, the Computing Division Head, and the Directorate that outlines progress, problems, and budget and schedule status, including comparisons of projected status versus actual status. The Directorate submits these reports to the DOE.

9.7.2 Technical Design Reports

A comprehensive Technical Design Report has been written that includes detailed technical descriptions of all BTeV Detector Project subsystems: detector components, trigger and data acquisition systems, integration and installation and pre-beam commissioning. This report provides the basis for the technical baseline of the BTeV Detector Project. The C0 Interaction Region Technical Design Report describes all aspects of the design and implementation of the high luminosity IR for C0. The C0 Outfitting Technical Design Report describes the design and implementation of work to provide the facilities required in C0 to support the BTeV experiment and the IR. The linkages and dependencies of these three projects are not especially complex and are captured in the Resource Loaded Cost and Schedule.

9.7.3 Meetings and Reviews

Various meetings between the Directorate, Project Management, Subproject Managers and the Collaboration will be held at appropriate intervals to ensure management of the overall project.

9.7.3.1 BTeV Project Management Group (PMG)

Meetings will be convened by the Deputy Director to monitor the progress of the project, as described in Section 4.10.3.

9.7.3.2 BTeV Technical Board

Frequent meetings between the Project Management and the Subproject Managers, as described in Section 4.10.2, will take place throughout the life of the project. Full discussion of all issues related to the status of the Project – technical, schedule, cost, personnel issues and needs – are covered here on a regular basis.

9.7.3.3 General Project Meetings

Eight to twelve general project meetings will be held each year that will provide the opportunity for project participants at every level to present status reports, discuss current issues and disseminate news and information. Whenever possible, these meetings will be synchronized with BTeV Collaboration meetings, held approximately monthly. These meetings are of general interest to anyone involved in the Project and serve to integrate diverse activities and provide an opportunity for physicists to criticize work in areas other than their own in this large project.

9.7.3.4 Subproject Meetings

Meetings shall be called by Subproject Managers, typically at a bi-weekly interval, to discuss status, progress, and issues directly related to the pertinent subproject, as well as its coupling to other parts of the Project. It is here that the consensus of the experts is developed. Possible departures from schedule and cost, and their mitigation, are discussed in these meetings prior to a more general presentation to and discussion with the BTeV Technical Board.

10 ACQUSITION STRATEGY PLAN

The acquisition strategy plan is detailed in the Acquisition Execution Plan for the BTeV Detector Project. In the following sections we summarize some of those plans.

10.1 Construction and Fabrication

Fabrication of components and subsystems will be done in-house using Fermilab facilities, by outside vendors working under subcontract to the Laboratory or BTeV collaborating institutions, and by BTeV collaborators at their home institutions. The responsibilities of each participating institution are further described in Memoranda of Understanding between the Project and the participating institution.

10.2 Procurement Plan

The components of the BTeV Upgrade will be acquired in a manner consistent with DOE and general Fermilab guidelines. Whenever possible, fixed-price competitive procurement practices will be followed. Purchase requisitions will be processed by the Fermilab procurements group after appropriate approval or by delegation to procurements groups of participating institutions.

10.3 Inspection and Acceptance

The Project Manager will be responsible for assuring that the appropriate procedures are in place at the subproject level to ensure that components and assemblies are inspected sufficiently to assure satisfaction of technical specifications. The subproject manager is responsible for devising appropriate inspections. Acceptance of components and systems will be done by those individuals directly responsible for them. When appropriate, inspection visits will be made to vendor shops, collaborating institutions and industrial firms fabricating or preparing components for the project.

10.4 System Testing and Commissioning

Once components are assembled and integrated into a subsystem, 'system tests' will be performed. These tests will involve the activation, debugging and tune-up of the full subsystem. Though such tests pertain to the system under study alone, they may require other subsystems to be operational to enable the tests. Examples of system tests include tests of the pixel detector readout system, response of the electromagnetic calorimeter to its calibration light source, and operation of the pixel and muon triggers on simulated data.

Commissioning consists of the process of integrating working subsystems into an operational experiment, and is the final stage of preparation for actual data taking. At this stage interactions and potential conflicts between distinct detector, trigger and readout systems are confronted for the first time. The commissioning process will evolve gradually, as subsystems are assembled and system tests performed. Lastly, full operation of the upgraded detector in the Collision Hall will begin.

11 TECHNICAL CONSIDERATIONS

Technical considerations are presented and examined in detail as part of the Technical Design Reports for BTeV Detector and extended TDR's for individual subsystems. A brief summary of the research and development considerations is presented below as well as the approach and responsibility for assurance of quality.

11.1 Research and Development

Subsystems and their components are designed to meet the requirements outlined in the TDR and in more detailed "Requirements Documents". Research and development is performed on detector components to ensure that the chosen technology will meet the physics and engineering requirements of the detector. Designs are documented in design reports and drawings are checked by peers, senior engineers, and/or managers.. Design reviews are performed. Design reports, specifications, drawings and other documentation will be delivered to FNAL to ensure that detector components can be supported and maintained.

11.2 Alternate Tradeoffs

The BTeV detector is a technically challenging detector. The guiding principle in its development has been to achieve the physics goals that formed the basis of the experiment's approval while minimizing costs and reducing cost and schedule risk. We have had the opportunity to conduct a substantial program of research and development. We have performed extensive bench tests, tests with cosmic rays, and beam tests to try to verify that our designs will meet the requirements of the experiment.

We have attempted, where possible, to chose proven technologies and commercial solutions. Where that has been impossible and it has been necessary to develop new devices or techniques, we have reduced risks by aligning ourselves with efforts by other HEP collaborations to develop similar devices or techniques.

In cases where several technologies are available, our choices have been guided by the principles above and by the goals of reducing complexity and exploiting commonality. In some cases, where two or more technologies have been very close together in their suitability, the deciding factor was the availability within the collaboration of expertise in the various choices.

11.2.1 Silicon Pixel Vertex Detector vs Silicon Strip Detector

This choice was driven by the requirement to use the vertex detector in the first level trigger. The amount of computer resources needed to do the pattern recognition is a very strong function of the pixel's long dimension. In the limit where the pixel long dimension is 2 cm, it becomes a "strip."This is to be compared to the BTeV pixel's large dimension of only 0.04 cm. The computer time to eliminate fake tracks that appear using a strip system goes up by much more than an order of magnitude and the efficiency is lower. The cost and complexity of implementing a system with more than ten times as much computing is prohibitive.

11.2.2 Use of 0.25 μm CMOS technology for the pixel readout chip vs. conventional radiation-hard technology

The development cost of radiation-hard pixel readout chips was very high. Typical prototype runs cost $250,000 and, even worse, required 8-10 months. Design runs competed with demand from military and other high priority customers. Technologies changed rapidly, with a characteristic time that was less than the elongated design cycle.

BTeV participated in a study of the radiation hardness of the commercial 0.25μm CMOS technology. This process is available from multiple vendors and has turned out to be exceedingly radiation hard. With the shorter and less expensive design cycles, we have made excellent progress towards designing the final pixel readout chip. We note that the use of this technology by other HEP experiments has allowed us to share in production runs and thereby reduce development costs even further.

11.2.3 Choice of lead tungstate crystals for the electromagnetic calorimeter

We began with 3 options that were sufficiently radiation hard. Lead scintillator did not meet our resolution requirements. Liquid Krypton was deemed by the Fermilab Particle Physics Division (PPD) to be operationally unacceptable for the C0 Collision Hall. Tests we performed at Protvino demonstrated that lead tungstate satisfied our resolution requirements and were sufficiently radiation hard to survive in the BTeV environment.

Because of the high cost of lead tungstate,we did a series of studies to determine the physics “payback" of various angular coverage. Studies with BTeVGEANT showed that the physics payback is slight after 200 mr angular coverage and the cost of the detector doubles if one extends the coverage from 200 mr to 300 mr, which is the full angular acceptance of BTeV.

11.2.4 Hybrid Photodiodes vs MultiAnode Photomultipliers for the Ring Imaging Cerenkov Counter

Cherenkov photons produced in the gas radiator in the wavelength region between 280 - ~650 nm need to be detected efficiently and their position needs to be measured to an accuracy of 0.5 mr requiring square pixels no larger than 6mm^2. There are two feasible technologies that can be used. One utilizes the “Hybrid Photo-Diode," (HPD) a device, produced by DEP in the Netherlands, that converts photons to electrons on a photocathode and then accelerates them through 20 keV where they are detected in a pixelated silicon detector. The signal is approximately 5000 electrons.

An equally usable system can be made from Multianode Photo-Multiplier Tubes

(MAPMT) produced by Hamamatsu. This device is simply a pixelated photomultiplier tube that produces a signal proportional to the gain, typically on the order of 10^5 electrons, when the applied voltage is about 900 V. We had chosen the HPD system originally because it offered to yield about 20% more Cherenkov photons and was significantly less expensive than the MAPMT's. This was judged to offset the greater difficulty of detecting the smaller signals and using a 20 kV high voltage system. The MAPMT was improved about one year ago by greatly reducing a rather large inactive border. The price for the MAPMT also was lowered. Our simulations show that now both systems would record almost identical numbers of Cherenkov photons. Since there is only one manufacturer for each device we have left open the choice of which photon detector to ultimately purchase until we can obtain final quotes for each system. In Sept. of 2000 both systems had comparable costs. By March 2004 the rapid rise in the Euro with respect to the US dollar has made the HPD based system about $1 M more costly than the MAPMT based system. We have developed electronics for both systems. Mechanical designs, support systems etc. have been worked out for both photon detectors. Since the MAPMT is easier to operate and now cheaper we have changed to this photon detector for our baseline.

11.2.5 Liquid vs Aerogel Radiator for Ring Imaging Cerenkov Counters

Identifying low momentum kaons is very important for flavor tagging of the other B for CP violation and mixing studies. Unfortunately the gas radiator RICH system is incapable of separating kaons from protons below track momentum of 3 GeV/c. A proposal by the late T. Ypsilantis was to use a thin aerogel slab as a radiator in front the gas and to use the gas photon detector system to detect the photons. LHCb has, in fact, adopted this solution. Our simulations showed that this system would not provide adequate separation
as the large radius aerogel rings, populated by approximately 10 Cherenkov photons would be swamped by the many gas rings with approximately 60 photons. Our simulations looked promising before we included the many electrons produced by photon conversions in the beam pipe and other material.

We then developed an alternative system using a 1 cm thick liquid C_5F_{12} radiator in front of the gas, but with a dedicated photon detection system using 5000 3-inch diameter photomultiplier tubes placed along the sides of the gas volume.

11.2.6 Choice of single-sided vs double-sided silicon for the forward Microstrip tracker

The use of double-sided silicon strips at first appeared attractive from the standpoint of minimizing the material in the detector. However, experience from the construction of the silicon strip detectors for Fermilab Run 2 revealed many difficulties at achieving good yield that led to schedule delay. Single-sided 0.25mm detectors are now commodity items. After a review of the effect of the extra material, we decided that a single-sided system could meet the requirements of BTeV and would be less costly and have smaller cost and schedule risk.

11.2.7 Commercial vs In-House Engineered Switch for Data Acquisition System

BTeV needs a very high speed switch to merge data fragments from an individual event into a contiguous record for the event. We believed that no commercial switch could handle rates as high as 7.5 MHz, which is the maximum possible crossing frequency at the Tevatron.. A review committee strongly argued that we had seriously underestimated the software development needed to support such a device and suggested that we look at commercial alternatives. A commercial solution would come with the required software and would largely eliminate these development costs. We found “custom-commercial" switches that had a reasonable chance of solving the problem but were very expensive. We studied the cost of separating the Data Acquisition into parallel highways, typically 8, and feeding them in round-robin fashion. This reduced the peak data rate into any subsystem by a factor of 8 and permitted us to use conventional network switching technology, which is inexpensive, reliable, and well-supported. This solution required each data source to be connected to each highway, or a factor of 8 more connections. It turned out that 8 times as many lower speed links did not cost any more than 1 high speed link. We have now gone to an all commercial technology. Recent reviewers have endorsed this approach because of reduced cost and complexity.

11.2.8 General Approach to Selection of Components for the C0 Interaction Region

R&D on accelerator magnets and supporting components is time-consuming and expensive. We have chosen to use standard components wherever possible. In particular, Fermilab has worked on the development of the LHC low beta quadrupoles. With some modifications to the cryostat, this design will be used for the IR. Since tooling and expertise exist, this will cost less and take the less time than any other solution that can achieve the requirements set for the IR. Similarly, standard Fermilab interlocks, instrumentation, controls, and power supplies will be used wherever possible.

11.3 Quality Assurance Program

Quality Assurance is an integral part of the design, fabrication and construction of the BTeV Project. Special attention is paid to items that are most critical to the schedule and performance requirements of the Project. All work performed at Fermilab will draw on the guidelines and criteria set out in the Fermilab Quality Assurance Program (FQAP). These include:

- management criteria related to organizational structure, responsibilities, planning, scheduling, and cost control;
- training and qualifications of personnel;
- quality improvement;
- documentation and records;
- work processes;
- engineering and design;
- procurement;
- inspection and acceptance testing;
- assessment

Work done elsewhere will be expected to satisfy these or similar standards.

12 INTEGRATED SAFETY MANAGEMENT

This section describes the policies for ensuring that Environmental, Safety and Health (ES&H) considerations are adequately addressed within the BTeV Project activities. The information below provides an overview of key issues. Policies, procedures and descriptive information are contained in the BTeV ES&H Implementation Plan. ES&H is a line management responsibility and will be implemented down through the subsystem organizations.

12.1 Overview

Fermilab subscribes to the philosophy of Integrated Safety Management (ISM) for all work conducted on the Fermilab site and requires its subcontractor and sub-tier contractors to do the same. Integrated Safety Management is a system for performing work safely and in an environmentally responsible manner. The term “integrated” is used to indicate that the ES&H management systems are normal and natural elements of doing work. The intent is to integrate the management of ES&H with the management of the other primary elements of work: quality, cost, and schedule. The seven principles of ISM are as follows:

(1) Line Management Responsibility for Safety: Line management is responsible and accountable for the protection of the employees, the public and the environment.

(2) Clear Roles and Responsibilities: The roles and responsibilities, and authority at all levels of the organization, including potential sub-tier contractors are clearly identified.
(3) Competence Commensurate with Responsibility: Personnel possess the experience, knowledge, skills and abilities that are necessary to discharge their responsibilities.
(4) Balanced Priorities: Resources are effectively allocated to address safety, programmatic and operational considerations. Protecting the public, the workers and the environment shall be a priority whenever activities are planned and performed.
(5) Identification of Safety Standards and Requirements: Before work is performed, the associated hazards are evaluated and an agreed upon set of safety standards and requirements are established which will provide adequate assurance that the public, the workers and the environment are protected from adverse consequences.
(6) Hazard Controls Tailored to Work Being Performed: Administrative and engineering controls, tailored to the work being performed, are present to prevent and mitigate hazards.
(7) Operations Authorization: The conditions and requirements to be satisfied for operations to be initiated and conducted are clearly established and understood by all.

The ES&H program at BTeV is intended to ensure that all relevant and necessary actions are taken to provide a safe working environment at FNAL for the design, construction, installation, test, operation and decommissioning of the BTeV detector. The BTeV detector was designated a Low Hazard Radiological Facility and the Safety Envelope was approved in 200X. The Directorate, advised by the ES&H Section, will determine the need for updates or addenda to the BTeV Safety Analysis Document.

12.2 Objectives

The following general objectives have been established by FNAL for the ES&H program for detectors:

- Establish and administer an ES&H program that promotes the accomplishment of FNAL ES&H objectives for employees and non-employees.
- Protect the general public and the environment from harm.
- Comply with federal, state and local laws, rules and regulations.
- Prevent personnel injury or loss of life during detector-related work.
- Prevent damage to equipment caused by accidents during detector-related work.
- Prevent any environmental contamination during detector development, fabrication, commissioning and operation.

12.3 Organization and Responsibilities

The ES&H program for the Project is the responsibility of the Project Manager. The Project Manager and his designees are responsible for establishing policies and requirements for ES&H during development and commissioning of the detector, and related experimental systems.

The Project Manager has the responsibility for identifying specific ES&H issues and risks, and for ensuring that Subproject Managers establish appropriate safeguards and procedures for addressing those risks for each subproject. The Project Manager and the Subproject Managers are the laboratory line management on matters of environment, safety, and health for the Project. The Project Manager is also responsible for ensuring that adequate safety documentation is provided for installation and operation of the upgraded detector. The resources of the Particle Physics Division ES&H Department are available to the Project Manager and Subproject Managers upon request. Ad hoc ES&H review committees, reporting directly to the PPD Head, will be assigned as appropriate.

12.4 Documentation and Training

The BTeV Project Manager is responsible for providing, as required, specific requirements and procedures, as well as hazard assessments, and other documents to comply with DOE and FNAL requirements. BTeV ES&H documents are defined in the BTeV Operations Guidelines Manual.

Those who are on the BTeV project at the FNAL site will be provided with the training and information necessary to reduce the risks associated with their work and to ensure their safety. Briefings and presentations will be made to all managers and supervisors to communicate ES&H policies, documentation and information associated with assuring safety of BTeV activities. Job-specific training will be provided on issues including electrical safety, cryogenic safety, radiation safety, and chemical safety, as well as issues related to detector transportation, installation, and testing activities. Proficiency testing is performed to gauge comprehension.

All visitors to BTeV will be informed of FNAL ES&H rules and procedures applicable to their visit. In general, visitors will not be allowed to work in areas without the advance permission of the BTeV Project Manager (PM) or his designee. All visitors to BTeV must be accompanied by a Host who is familiar with FNAL and BTeV ES&H rules and procedures. Hosts are responsible for the safety of the visitors they accompany.